THE LIBRARY OF CONGRESS
1800

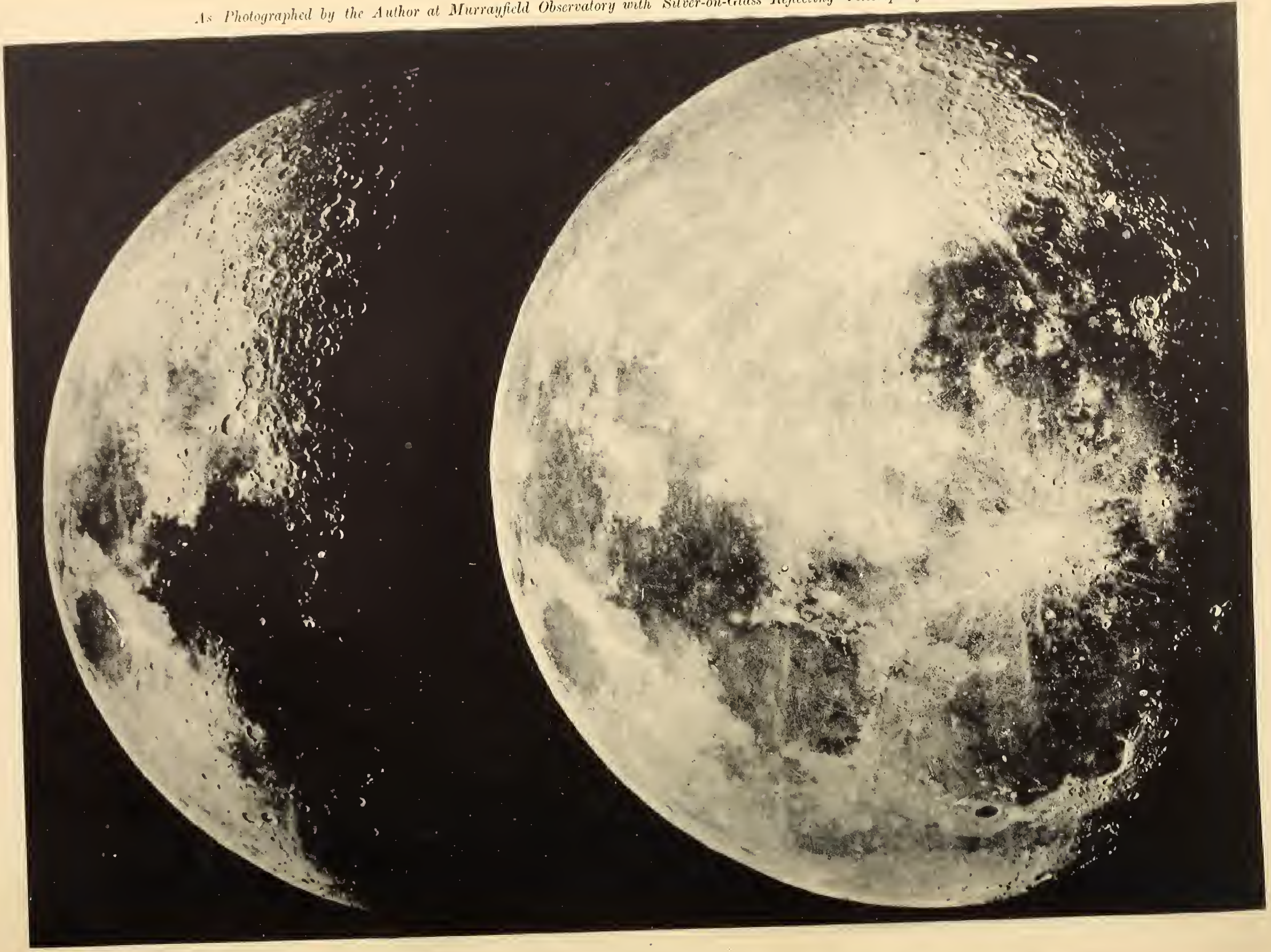
RECEIVED
JUN 7 1892
LIBRARY NAVY DEPARTMENT

A POPULAR

HANDBOOK AND ATLAS OF ASTRONOMY.

THE MOON

As Photographed by the Author at Murrayfield Observatory with Silver-on-Glass Reflecting Telescope of 13 inches Aperture.



A POPULAR

HANDBOOK AND ATLAS OF ASTRONOMY.

Designed
AS A COMPLETE GUIDE TO
A Knowledge of the Heavenly Bodies: and as an Aid
to those possessing Telescopes.

BY

Sir WILLIAM PECK, F.R.S.E., F.R.A.S.,
ASTRONOMER TO THE CITY OF EDINBURGH, LECTURER ON ASTRONOMY,
AUTHOR OF "THE CONSTELLATIONS AND HOW TO FIND THEM," ETC.

CONTAINING
FORTY-FOUR LARGE PLATES, AND NUMEROUS ILLUSTRATIONS, DIAGRAMS, &c.

RECEIVED
JUN 7 1892

New York:
G. P. PUTNAM'S SONS, 27 & 29 WEST TWENTY-THIRD ST.;
LONDON: GALL AND INGLIS.

1891.

QB44
.P4

3
Copy

PREFACE.

In the production of this work the Author had in remembrance what he had one time seen so well stated —viz., "That the public now demand of those devoted to science, that they shall not confine the knowledge they have such favoured opportunities of acquiring, to the lecture-room, but shall render it, as far as practicable, available to the well-informed of all professions." While keeping this in view, however, he did not think it necessary that the present work should be of an elementary nature, nor, on the other hand, an advanced work, but one well suited to occupy an intermediate position, and to give the kind of information so often required, yet sometimes difficult to obtain from ordinary works on the science.

The various subjects, therefore, are described in a popular manner, while, at the same time, complete and accurate information is given in the principal departments of modern astronomy. More than this, however, is occasionally required, and so numerous important Tables, which are too often omitted in works of a similar nature, have been inserted for ready reference on the part of the student. The object has been, in short, to supply the knowledge that is required by every fairly well educated individual—viz., to give a clear, accurate, and popular account of the nature of the various heavenly bodies, and their position in the universe.

In the first chapter, in a condensed form, there is presented the Author's investigation as to the origin of the Constellations, which at some future time he hopes to fully elaborate in a special work. These ideas are now for the first time published, and are the outcome of many years' study of the subject, particularly from a source that, strangely enough, has not hitherto been much considered—the positions of the old constellation figures, and the testimony of the star-groups themselves.

The principal subjects discussed in the various chapters are arranged under different heads, an arrangement which, it is hoped, will facilitate reference, and at the same time give a clearer idea of the more important points. It will be seen that the large plates—45 in all—form a special feature of the volume. In most astronomical works a considerable amount of clearness is lost for want of sufficiently enlarged diagrams. The present work, it is hoped, will be entirely free from this defect. The plates of views, charts, diagrams, &c., have been specially constructed by the Author himself, and no labour has been spared in making them as accurate and comprehensible as possible.

The Atlas proper will be found of the greatest assistance to all who are desirous of obtaining, in the simplest manner possible, an accurate knowledge of the sidereal heavens. The charts being printed on a dark blue ground with white stars (which is decidedly preferable to the ordinary method of black stars on a white ground), the constellations are represented in a natural manner, and the identification of stars greatly facilitated. The twelve large charts, which embrace the whole star-sphere, combined with the twenty-four index horizon maps, whereby the position of the constellations in the sky can be ascertained from any part of the globe, and for any time of the year, form an Atlas which, we hope, will be one of the plainest and most complete for ordinary purposes hitherto published.

Throughout the work the wants of the telescopist have not been lost sight of, especially in the Atlas portion, which will be found to contain the fullest information about the various objects which may with advantage be examined by a small instrument. In short, it is believed that little has been omitted that would have in any way increased the attractiveness and usefulness of the volume, and that would increase its value as a suitable companion for all those desirous of possessing a knowledge of the heavenly bodies.

Altogether, it is hoped that the volume may be the means of creating an interest, however slight, in the wonders that lie stored in the depths of infinite space.

MURRAYFIELD MID-LOTHIAN, 1890

Contents.

PAGE

PREFACE, ... v

CONTENTS, ... vii

LIST OF LARGE PLATES, ... ix

LIST OF ILLUSTRATIONS IN THE TEXT, ... x

LIST OF TABLES OCCURRING THROUGHOUT THE WORK, ... xi

CHAPTER

I. *THE CONSTELLATION FIGURES—THEIR PROBABLE ORIGIN—*

The oldest records of the Constellations; The Sphere of Eudoxos; The use of the Zodiac; The country in which the Constellations were originated; The epoch at which they were invented, ... 1

II. *MOVEMENTS OF THE EARTH WHICH AFFECT THE APPEARANCE OF THE HEAVENS—*

Diurnal Motion; Annual Motion; Precession of the Equinoxes; Nutation; Aberration; Proper Motion; Alterations in the appearance of the Constellations; The actual velocity of Stars, ... 11

III. *THE SIDEREAL HEAVENS—*

The Stars; their distances; Parallax; The Nature of the Stars; Different orders of Stars; Double and Binary Stars; Variable and Temporary Stars; Star Clusters and Nebulæ; The Number of the Stars; The Milky Way, ... 19

IV. *THE SUN—*

Its distance from the earth according to the ancients; Modern determinations of the Sun's mean distance; Its Volume and Mass; Sunlight and Heat; Sunspots; Faculæ; The Sun's Interior; The Solar Atmosphere; Principal Facts about the Sun, ... 33

V. *THE PLANETARY SYSTEM AND ITS VARIOUS MEMBERS,* ... 39

THE PLANETS NEAREST THE SUN, ... 40

MERCURY; Transits of Mercury, ... 41

VENUS; Transits of Venus, ... 43

THE EARTH; Its movements; The Year; The Day; Variation of the eccentricity of the terrestrial orbit; The observed obliquity of the Ecliptic for nearly 3000 years, ... 45

MARS; Its continents and oceans; Its snow caps; Its satellites; Their size; Their rapid movements, ... 48

THE ASTEROIDS; Their position; Their number, ... 51

JUPITER; Its gigantic size and mass; Its cloud zones; Its atmospheric storms; Its heat; Its satellites, ... 53

SATURN; The wonderful ring system; Its dimensions and nature; The satellites; A miniature of the Solar System, ... 55

URANUS; Its Moons; Their paths, ... 58

NEPTUNE; Its wonderful discovery; The direction of its rotation, ... 59

TRANS-NEPTUNIAN PLANET, ... 60

Principal elements of the Planetary System for 1900, ... 61

Principal elements of the Satellites, ... 62

Principal Facts about the Planets, ... 62

VI. *COMETS AND METEORS—*

Comets; Their paths and movements; Different classes of comets; The heads of comets; Their tails; The principal comets belonging to the Solar System; Meteors and Meteor Systems; Occurrence of Meteor Showers; Meteorites; Their size and composition; The Origin of Comets and Meteors, ... 63

CHAPTER PAGE

VII. *THE MOON—*

The Lunar Phases; The Month; different kinds of month; The Lunar Orbit; Dimensions of the Lunar Globe; The Rotation of the Moon; Libration in latitude and longitude; Telescopic appearance of the Lunar Globe; Lunar Mountains and Craters; Diameters of the more interesting craters and walled plains; Lunar Elements, ... 72

VIII. *ECLIPSES OF THE SUN AND MOON—*

The fear produced by eclipses in superstitious ages; The Saros; Eclipse Seasons; Eclipses of the Moon; Eclipses of the Sun; Solar Eclipses till 1900; Lunar Eclipses till 1900, ... 82

IX. *ASTRONOMICAL INSTRUMENTS FROM THE EARLIEST TIMES—*

The instruments used by the ancients; The Gnomon; The Astrolabe; The Parallactic Rules; The invention of the Telescope; Refractors and Reflectors; The Modern Reflector; Application of the Telescope; The Parallel Wire Micrometer; The Transit Instrument; The Observatory Clock; The Equatorial; The Spectroscope; The Altitude and Azimuth Instrument; The Sextant, ... 90

Suitable instrument for a practical study of the heavens, and method of using it, ... 108

X. *EXPLANATION OF THE STAR CHARTS—*

The Ancient and Modern Constellations; Designation of individual Stars; Magnitudes of Stars; Number of Stars of each magnitude visible to the unaided eye; Star Charts; Explanation of Tables, &c., ... 112

TABLE 1. THE CONSTELLATIONS INSERTED IN THE STAR CHARTS, ... 118

„ 2. FOR FINDING THE APPARENT TIME OF SUNRISE AND SUNSET AT DIFFERENT LATITUDES FOR ANY TIME OF THE YEAR, ... 120

„ 3. THE EQUATION OF TIME, ... 121

„ 4. THE DURATION OF TWILIGHT AT DIFFERENT LATITUDES, ... 121

„ 5. FOR FINDING THE STARS VISIBLE AT ANY DATE AND HOUR IN THE NORTHERN HEMISPHERE, ... 122

„ 5*a*. FOR FINDING WHEN A STAR IS ON THE MERIDIAN, ... 123

„ 6. FOR FINDING THE STARS VISIBLE AT ANY DATE AND HOUR IN THE SOUTHERN HEMISPHERE, ... 124

„ 6*a*. FOR FINDING WHEN A STAR IS ON THE MERIDIAN, ... 125

„ 7. SIDEREAL TIME AT NOON FOR VARIOUS DATES, ... 126

„ 8. FOR FINDING THE TIME OF RISING OR SETTING OF A STAR, ... 126

„ 9. STAR CATALOGUE GIVING THE NAMES, POSITIONS, AND MAGNITUDES OF THE MORE IMPORTANT STARS FOR EPOCH 1890, ... 127

INDEX TO THE CHART OF THE MOON, ... 136

CATALOGUE OF INTERESTING OBJECTS THAT MAY BE SEEN WITH A TELESCOPE, ... 150

INDEX, ... 173

LIST OF LARGE PLATES.

PAGE
Frontispiece. Photographs of the Moon taken by the Author, ... *Facing Title.*
Photographs of an Eclipse of the Moon taken by the Author, ... 86
PLATE 1. The Old Constellation Figures in the Northern Hemisphere, ... 2
,, 2. Do. do. Southern Hemisphere, ... 2
,, 3. The Positions of the Constellations in the Northern and Southern Hemispheres 14 700 years ago, ... 10
,, 4. The Stars Visible to the Naked Eye in the Northern and Southern Hemispheres, ... 19
,, 5. The Telescopic Appearances of the more interesting Double Stars, ... 24
,, 6. The Pleiades, from a Photograph, showing the Nebulæ surrounding the Brighter Stars, ... 26
,, 7. Star Clusters, ... 28
,, 8. Nebulæ, ... 29
,, 8*a*. The Spiral Nebula in CANES VENATICI, ... 30
,, 8*b*. The Dumb-bell Nebula as seen by Lord Rosse, } ... 32
Nebulæ as seen by Sir J. Herschel, }
,, 9. The Sun, showing the Sun-spots, Faculæ, Prominences, Corona, &c. (*Coloured*), ... 36
,, 10. The Comparative Sizes of the Planets (*Coloured*), ... 39
,, 11. The Orbits of the Inner Planets, ... 42
,, 12. Chart of the Planet Mars in Two Hemispheres, from Recent Observations by Schiaparelli (*Coloured*), ... 50
,, 13. The Solar System; with Orbits of Comets; and Enlarged Chart of the Orbits of the Principal Asteroids, 52
,, 14. The Orbits of the Satellites of the Planets, ... 54
,, 15. Telescopic Views of the Planets (*Coloured*), ... 56
,, 16. Views of the More Remarkable Comets, ... 66
,, 17. Lunar Craters, ... 78
,, 18. Diagram of Solar and Lunar Eclipses, ... 88
,, 19. Spectra of the Sun, Stars, Nebulæ, &c. (*Coloured*), ... 106
,, 20. Chart of the World on the Stereographic Projection, showing the difference of time between different places; the duration of the longest and shortest days at different latitudes; and the positions of the principal Observatories of the world (*Coloured*), ... 116
Picture Chart of the Moon, ... 136

STAR CHARTS.

CIRCULAR MAPS, Nos. 1 to 12, for Finding the Stars Visible at Different Dates and Hours in the Northern Hemisphere, ... 137-142
,, ,, ,, 13 to 24, for Finding the Stars Visible at Different Dates and Hours in the Southern Hemisphere, ... 143-148
DECLINATION. RIGHT ASCENSION.
CHART 1. Indicates from 50° N. to 90° N., and from 0 h. to 24 h., ... 150
,, 2. ,, 10° S. to 50° N., ,, 21 h. ,, 3 h., ... 152
,, 3. ,, 10° S. to 50° N., ,, 2 h. ,, 8 h., ... 154
,, 4. ,, 10° S. to 50° N., ,, 7 h. ,, 12 h., ... 156
,, 5. ,, 10° S. to 50° N., ,, 12 h. ,, 17 h., ... 158
,, 6. ,, 10° S. to 50° N., ,, 16 h. ,, 22 h., ... 160
,, 7. ,, 10° N. to 50° S., ,, 0 h. ,, 5 h., ... 162
,, 8. ,, 10° N. to 50° S., ,, 4 h. ,, 10 h., ... 164
,, 9. ,, 10° N. to 50° S., ,, 9 h. ,, 15 h., ... 166
,, 10. ,, 10° N. to 50° S., ,, 14 h. ,, 20 h., ... 168
,, 11. ,, 10° N. to 50° S., ,, 19 h. ,, 0 h., ... 170
,, 12. ,, 50° S. to 90° S., ,, 0 h. ,, 24 h., ... 172
,, 13. The Zodiacal and Equatorial Regions of the Star Sphere, ... 172

LIST OF ILLUSTRATIONS

Occurring in the Text.

FIG. PAGE

1. The Sphere of Eudoxos, ... 1
2. Ophiuchus and Hercules, ... 4
3. Constellation Figures in an MS. of the 4th Century A.D., ... 7
4. Diagram showing the Paths of Stars on the Star Sphere for Latitude 50°, ... 11
5. Diagram showing the Stars Visible and Invisible for Latitude 50°, ... 11
6. Diagram showing the Paths traced out by the Opposite Ends of the Earth's Axis owing to the Precession of the Equinoxes, ... 13
7. Diagram showing the Path traced out by the Poles owing to Nutation, ... 15
8. Diagram explaining the Aberration of Light, ... 16
9. Diagram showing the Relative Proportion of the Proper Motion of Different Stars, ... 17
10. Alterations in the Appearance of some of the Constellations, 100,000 Years hence, owing to Proper Motion, 17
11. Diagram showing how the Actual Velocity of a Star is Calculated, ... 18
12. Diagram showing how the Distance of a Star is Measured, ... 19
13. The Comparative Sizes of the Sun and *Sirius*, ... 22
14. Curves showing the Variation of Magnitude of Different Classes of Stars, ... 26
15. The Milky Way as viewed with a Telescope, ... 32
16. Diagram showing the Ratio of the Orbit of the Moon to the Diameter of the Sun, ... 35
17. The Radiant Point of the November Meteors, ... 68
18. Meteoric Stones, ... 70
19. Diagram showing how the Orbit of the Moon is always Concave to the Sun, ... 74
20. The Comparative Sizes of the Earth and the Moon. ... 75
21. The Meridian Instrument of Eratosthenes, ... 91
22. The Equatorial Astrolabe, ... 92
23. The Ecliptic Astrolabe, ... 92
24. The Parallactic Rules, ... 93
25. The Refracting Telescope—(*a*), Galilean Telescope; (*b*), Old Refracting Telescope invented by Kepler; (*c*), Modern or Achromatic Refracting Telescope, ... 95
26. The Great Lick Refracting Telescope, ... 96
27. Gregorian Reflecting Telescope, ... 97
28. Cassegrainian Reflecting Telescope, ... 97
29. Newtonian Reflecting Telescope, ... 97

29*a*. The First Reflecting Telescope, made by Sir Isaac Newton, ... 98

30. The Parallel Wire Micrometer, ... 100
31. The Transit Instrument, ... 101
32. The Field of View of the Transit Instrument, ... 101
33. The Compensated Pendulum, ... 103
34. The Equatorial Telescope, showing the "English" Method of Equatorial Mounting, ... 104
35. A Modern Refractor Equatorially Mounted, ... 104
36. A Modern Reflector, showing the "German" Method of Equatorial Mounting, ... 105
37. Simple Spectroscope, ... 105
38. The Author's Spectroscope, ... 106
39. Altitude and Azimuth Instrument, ... 107
40. The Sextant, ... 108
41. Stands for Small Telescopes, ... 110
42. Different Kinds of Eye-pieces, ... 110
43. Diagram explaining the Different Symbols employed in the Star Charts, ... 116

LIST OF TABLES.

PAGE
The Actual Velocity of Stars, ... 18
Ancient and Modern Positions of the more Conspicuous Stars, ... 14
Binary Stars; their Periods of Revolution, and the Magnitudes of their Components, ... 25
Different Classes of Stars, and the Principal Members of each Class, ... 23
The more Important Comets belonging to the Solar System and their Periods of Revolution, &c., ... 65
The Apparent and Actual Lengths of the Tails of Comets, ... 67
The Constellations, Ancient and Modern, ... 113
The Constellations indicated in the Star Charts, and the Charts in which each occurs, ... 118
The Length of a Degree of Latitude at Different Distances from the Equator, ... 45
The Apparent Diameter of the Earth's Shadow in Lunar Eclipses, ... 87
The Distances of the Vertex of the Lunar Shadow from the Earth in Solar Eclipses, ... 89
The Distances of the Nearer Stars, their Annual Parallax, and the Time taken by their Light in journeying to the Earth, ... 21
The Distances of the Planets from the Sun according to "Bode's Law," and their Actual Distances, ... 51
The Distance of the Sun according to Ancient Astronomers, ... 33
Modern Determinations of the Sun's Mean Distance, ... 34
The Eccentricity of the Terrestrial Orbit for 200,000 Years, ... 46
Elements found in Meteorites, ... 71
Elements known to exist in the Solar Atmosphere, ... 106
The Elements from which Halley discovered the Periodicity of his Comet, ... 64
Solar Eclipses till 1900, ... 83
Lunar Eclipses till 1900, ... 84
Lunar Elements, ... 80
The Principal Elements of the Planetary System for 1900, ... 61
The Principal Elements of the Satellites of the Planets, ... 62
The Equation of Time, ... 121
The Greek Alphabet, ... 114
The Diameters of the more Interesting Lunar Craters and Walled Plains, ... 79
The Principal Lunar Mountains, Seas, Gulfs, &c., ... 136
Meteor Systems; their Periods, Duration and Time of Visibility, &c., ... 69
The Lengths of Different Kinds of Months, ... 73
The Number of Stars of each Magnitude to the 20th, ... 29
The Number of Stars of each Magnitude Visible to the Naked Eye, ... 115
The Observed Obliquity of the Ecliptic for nearly 3000 Years, ... 47
The Old Method of Designating Star Magnitudes, ... 115
Principal Facts about the Planets, ... 62
Principal Facts about the Sun, ... 38
The Dimensions of Saturn's Rings, ... 57
Sidereal Time at Noon for Different Dates throughout the Year, ... 126
To Find the Time of a Star's Rising or Setting, ... 126
The Magnitudes of Stars Visible with Telescopes of Different Apertures, ... 30
The Apparent Time of Sunrise and Sunset at Different Latitudes and Dates, ... 120
Catalogue of the Names, Magnitudes, and Positions of the more Important Stars for 1890, ... 127
To Find the Stars Visible in the Northern or Southern Hemispheres at Different Dates and Hours, ... 122
To Find when a Star is on the Meridian, ... 122
Temporary Stars, and the Dates of their Appearance, ... 27
Transits of Mercury, ... 42
Transits of Venus, ... 44
The Duration of Twilight at Different Times throughout the Year and at Various Latitudes, ... 121
The Dividing Power of Telescopes of Different Diameters, ... 111
The more Interesting Variable Stars, their Periods, and Range of Variability, ... 27

"And is creation not a work of skill
In its grand outline, in its parts minute,
That we should mark its movements, trace its laws,
Observe its fine consenting harmonies?"—ADDISON.

"That which may profit and amuse is gather'd from the volume of creation,
For every chapter therein teemeth with the playfulness of wisdom.

* * * * *

It is glorious to gaze upon the firmament, and see each distant shining world,
To study Nature, and find her grand but simple secrets,
The wonderful all-prevalent analogy that testifieth One Creator."—MARTIN TUPPER.

"Though still by them uncomprehended,
From these the angels draw their power,
And all Thy works, sublime and splendid,
Are bright as in Creation's hour."—GOETHE.

A POPULAR
HANDBOOK AND ATLAS OF ASTRONOMY.

CHAPTER I.

THE CONSTELLATION FIGURES—THEIR PROBABLE ORIGIN.

"The names of the constellations of the zodiac have not been given to them by chance."—*Laplace.*

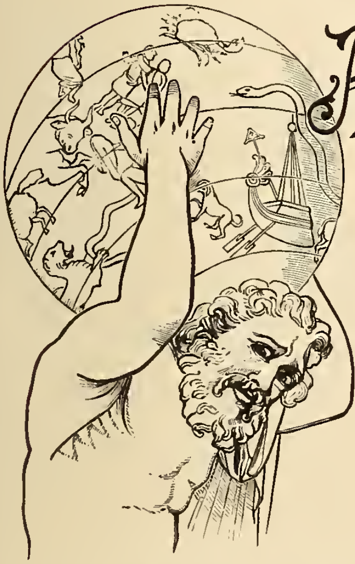


FIG. 1. THE SPHERE OF EUDOXOS.

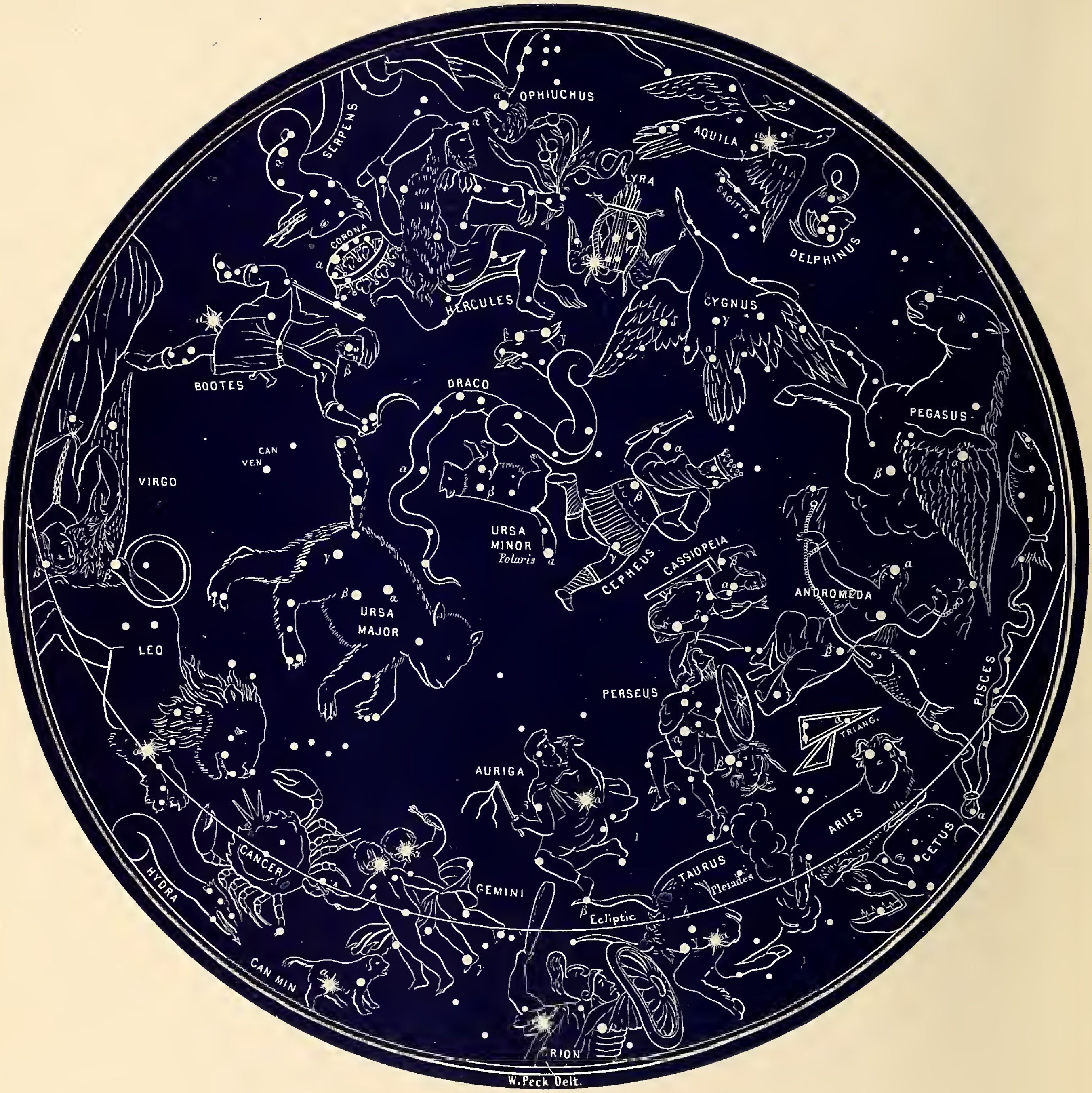
ASTRONOMY is undoubtedly the oldest as well as the noblest of the sciences. Ever since man began to look beyond his everyday wants, he has cast an inquiring eye on the mysterious orbs moving above him. At an age in the world's history, long previous to that which saw the great dynasties of ancient Egypt, Babylon, Assyria, and Persia, springing into existence, semi-civilised man had not failed to notice and wonder at the magnificent panorama of nature revealed in the marvellous grandeur and the constantly altering appearance of the celestial sphere. The splendour of the "Orb of Day," the softer beauty of the "Queen of Night," the unaccountable movements of the "five wandering fires," the planets, and the countless hosts of smaller orbs of various hues and degrees of brightness, must in succession have attracted his attention, and awakened his most superstitious fears and fancies. To him the sun appeared as the great author of all things, and the stars as secondary powers, whose faces were covered at the approach of the sun-god's splendour. To him the constantly changing moon was a special mystery, appearing as a deity presiding over his destiny, warning him of dangers to be encountered, and doing battle with the other heavenly powers on his behalf. In these superstitious fancies the so-called science of astrology, as well as many religious beliefs, had their origin; for primitive man never seems to have cultivated the noble science of astronomy without connecting it with his own individuality and the secrets of the future.

That this belief in the power of the heavenly bodies was in existence at a time when the great laws of the universe were unknown is not to be wondered at, and in one respect it had a beneficial effect, as it did much to stimulate an inquiry into the movements and nature of the various orbs. The moon, from its rapid motion among the stars, and the phenomenon of its phases, was in all probability the first heavenly body carefully observed, from which observation there would soon result the discovery of its true path round the star sphere, and the time occupied by it in making a complete revolution. The information thus obtained would give rise to the invention of the first important time interval after the day—viz., a period of 28 days, or a complete sidereal revolution of the moon. This was probably the longest period of time measurement used by primitive man, or the earliest conception of a year, traces of which are seen in uncivilised parts of the world even at present. As the motion of the sun among the stars requires much more observational skill to discern than does the motion of the moon, the former must have been discovered at a much later epoch. When once noted, it would, from necessity, suggest the idea of dividing the stars into groups or constellations. All along the solar track means would be required to indicate the position of the great orb from day to day, and these could only be arrived at by noticing the position of the sun among the stars, or the place occupied by the stars with respect to the rising and setting sun. At first the star zone through which the moon and sun appeared to move, seems to have been divided into twenty-eight nearly equal spaces, representing the daily movement of the moon. When, however, the sun's motion came to be detected, this division gave way to a more important one, a soli-lunar division—that is, one of only twelve spaces, resulting from a combination of the apparent movements of the two orbs. Accordingly each of the twelve parts into which the star zone was now separated would represent the space traversed by the sun in the interval occupied by the moon in making a complete revolution—each space corresponding to the amount of solar motion in an interval of about thirty days. Now, as each space would naturally be divided into thirty parts, the great circle of the heavens would thus come to be divided into 360 parts, and originate the division of the circle into 360 degrees, and the ancient year into 360 days. The constellations of the zodiac, then, were in all probability the first invented, these being at first simply a rude kind of calendar dividing the year into twelve parts, or months, and by the nature of the constellation figure, indicating, at the time when the sun was in its midst, what the particular month was noted for. After a time, when the gyratory movement of the poles of the earth, or the precession of the equinoxes (explained in Chapter II.), caused the zodiacal constellations no longer to coincide with the solar calendar, the original use of the zodiac became lost, and its various figures, along with new constellations invented from time to time, became part of the elaborate systems of mythology and religions, a fact to which the existence of the Sphinxes (*Leo* and *Virgo*), Winged Bulls (*Taurus*), Rams (*Aries*), &c., bears testimony.

The above, however, tells us nothing of the *age* or the *country* in which the figures of the constellations were invented. That the country in which this important work of dividing that portion of the star sphere annually traversed by the sun into groups characteristic of the principal events taking place throughout the year, was entirely or almost cloudless, is certain, and several countries could be mentioned which meet this condition, as Egypt, Assyria, &c. But at what epoch it was commenced is not so easily decided. Even after minute research, it must be confessed it is only with great difficulty and caution that anything in the way of a date can be suggested. Reliable history does not carry us so far back as to throw any light on the subject, and, if the question is to be decided at all, it must chiefly be from the testimony of the star groups themselves.

When one examines a modern chart of the heavens, with the constellation figures thereon depicted, it is found that there are many, for the most part unimportant, groups of stars, which must have been named at a comparatively recent date, such as SEXTANS, OCTANS, PAVO, INDUS, &c. These, however, it is necessary to remove from the chart, so that the older figures can be seen to the greatest advantage. This has been done in Plates 1 and 2, which contain only what are known to be old constellation figures. In many cases, the names of the old groups have been changed by the various nations by whom they have been handed down to us, but, fortunately, this change of name is not of so much consequence, as their characteristic forms seem to have, for the most part, remained unaltered. Thus the Greeks, who are believed to have received the constellations from the ancient Egyptians, gave to each a Grecian name, while they retained the idea belonging to the group. The discovery at Rome of a sculptured marble globe of the heavens resting on the figure of Atlas (*see Fig.* 1) proves this to have been the case. On this sphere, which is the oldest known representation of the heavens, and believed to be an exact copy of the celebrated sphere of Eudoxos, the various constellations are clearly depicted. Now, we know that Eudoxos, before constructing his celebrated star globe, travelled into Egypt about the year 380 B.C., and received astronomical instruction from the priests there. This instruction, combined with his own observations, enabled him to write two important works, showing the

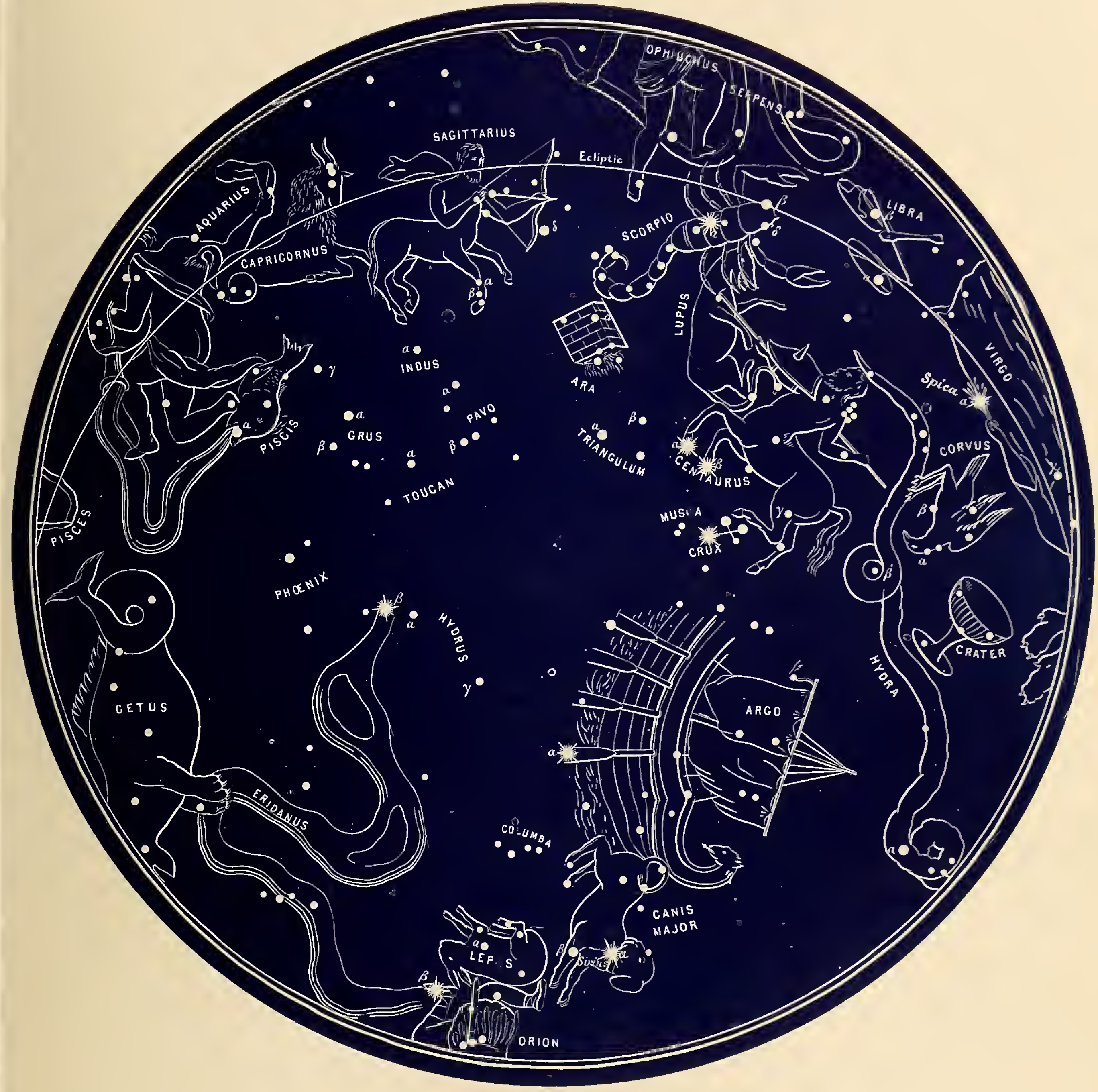
PLAT


OPHIUCHUS
SERPENS
AQUILA
LYRA
SAGITTA
DELPHINUS
CORONA
HERCULES
CYGNUS
BOOTES
DRACO
PEGASUS
CAN VEN
VIRGO
URSA MINOR
Polaris
CEPHEUS
CASSIOPEIA
ANDROMEDA
URSA MAJOR
LEO
PERSEUS
TRIANG.
PISCES
AURIGA
ARIES
CETUS
CANCER
HYDRA
GEMINI
TAURUS
Pleiades
Ecliptic
CAN MIN
RION
W. Peck Delt.

NORTHERN HEMISPHERE.

THE OLD CONS

ND 2.


OPHIUCHUS
SERPENS
SAGITTARIUS
Ecliptic
AQUARIUS
CAPRICORNUS
SCORPIO
LIBRA
LUPUS
ARA
INDUS
PAVO
GRUS
TOUCAN
TRIANGULUM
CENTAURUS
VIRGO
Spica
CORVUS
MUSCA
CRUX
PISCIS
PISCES
PHŒNIX
HYDRUS
CETUS
ERIDANUS
ARGO
CRATER
HYDRA
COLUMBA
CANIS MAJOR
Sirius
LEPUS
ORION

SOUTHERN HEMISPHERE.

TION FIGURES.

connection between the weather and the different positions of the constellations in the sky—viz., the *Phainomena*, or "Appearance," and the *Enoptron*, or "Mirror of Nature." Unfortunately, however, for astronomical science, these works of Eudoxos have been lost, and all the information we have of them is from one of the most popular of ancient works, the poem of Aratos, written about a century after the time of Eudoxos. As Aratos possessed no astronomical knowledge himself, he seems to have faithfully followed the description of the constellations given in the *Phainomena*, and thus his celebrated poem can be little more than a versification of the work of Eudoxos. In this poem, which must have been familiar to St. Paul, as he quotes from it, there is given a fairly minute description of the various constellation figures, and, at the same time, mention is made that these figures were invented in some very remote age antecedent to the time of Eudoxos.*

The oldest known records of the constellations only carry us back to about the year 400 B.C.; but their invention is undoubtedly much older, and was known to the Egyptians and Chaldeans long before that time. From the supposed connection between the Great Pyramid of Cheops and several of the star groups, the epoch of the construction of that building—about 2000 B.C.—has been thought by some to be identified with the division of the heavens into groups. But though, for astrological purposes, several of the constellations may have become connected with the Great Pyramid, it seems that the origin of the present arrangement of the *zodiac* is very much older. Others, again, have tried to connect Chaldea with the invention of the constellations, and they fix upon nearly the same epoch as that already mentioned; but while Chaldea and Assyria have undoubted historical claims, on account of their connection with very ancient astronomy, yet Egypt seems to be the country in which the zodiac at least was known at a very distant age. This we need not wonder at, as, of all countries in the world, Egypt seems at a very early time to have reached a high state of civilisation. At the time of Herodotus, 500 B.C., for instance, the Egyptians were more advanced in culture than any other people, and were considered to be the most ancient nation. From the priests, philosophers, and artisans of Thebes and Memphis, the countrymen of Hesiod and Homer received instruction in religion, science, and arts, and derived the groundwork from which was built up their elaborate system of mythology. From Egypt the Greeks learnt the system of writing history, as in that country, from the very earliest times, it had been the custom to transmit to posterity the records of past events. The Greeks also received many of their architectural ideas from the same people, and these ideas have never been surpassed for sublimity and grandeur of conception. Still further, it was from the philosophers of the Nile that Thales, six hundred years before our era, received the knowledge by means of which he was enabled to calculate eclipses, to determine the equinoctial and solstitial points, and to instruct his countrymen in the method of navigating their ships by observations of the stars. But even before Greece was in existence, the valley of the Nile was peopled by a highly civilised race, and this race, *four thousand* years ago, had made such great progress in the arts as enabled them to construct buildings which for size and grandeur have been the wonder of every subsequent age—a fact which points to a great antiquity, as this perfection could only have been the outcome of an advanced knowledge of the sciences, derived from the combined study of numberless generations.

It will not, then, be at all surprising if in our inquiry we are led to believe that the "land of the Pharaohs" was more or less connected with the figures of the constellations, at a time when other countries must have been in a state of barbarity. Owing to the precession of the equinoxes, the poles of the earth are made to point successively to various parts of the star sphere throughout the long period of about twenty-six thousand years. This produces a slow apparent movement of the stars, and a displacement of the constellation figures in the heavens; accordingly many of the imagined figures in the sky, which in ancient times, and at the time of their invention, appeared to be in their natural posture, are now considerably altered in position, and in some cases completely inverted. The constellation of HERCULES (*see Fig.* 2) is a striking example of this precessional effect.* When this figure was invented it could not have been situated as it now is, but, as described in the poem, kneeling, with the head upright. Now, as OPHIUCHUS appears to be quite as ancient as HERCULES, it also would be in an upright position, and as the head of the figure is close to the head of Hercules, and the body extending in the opposite direction, these constellations could only be seen in their true positions when the heads of the figures were near the *zenith* of the place from which they were viewed, the one constellation appearing upright to the north, the other to the south. This arrangement could only have taken place in a latitude of about 25 degrees north—the latitude of ancient Egypt. Again, the constellation of PEGASUS is at present seen in an inverted position; so also are the constellations of ANDROMEDA, CASSIOPEIA, &c., but in the past in the latitude of Egypt they were seen in more natural positions near the zenith, as in Plate 1. From the arrangement and the present positions of the old constellations, one is thus led to infer that it is to the ancient Egyptians we are indebted for the first division of the stars into constellations. When, however, we come to the arrangement of the zodiac, we see how intimately connected these constellations are with that most interesting of countries.

---

* "Some man of yore
A nomenclature thought of and devised
And forms sufficient found. For men could not
Or tell or learn the separate name of all:
Since everywhere are many, size and tint
Of multitudes the same, but all are drawn around.
So thought he good to make the stellar groups,
That each by other lying orderly,
They might display their forms. And thus the stars
At once took names, and rise familiar now."

See Translation by Robert Brown.

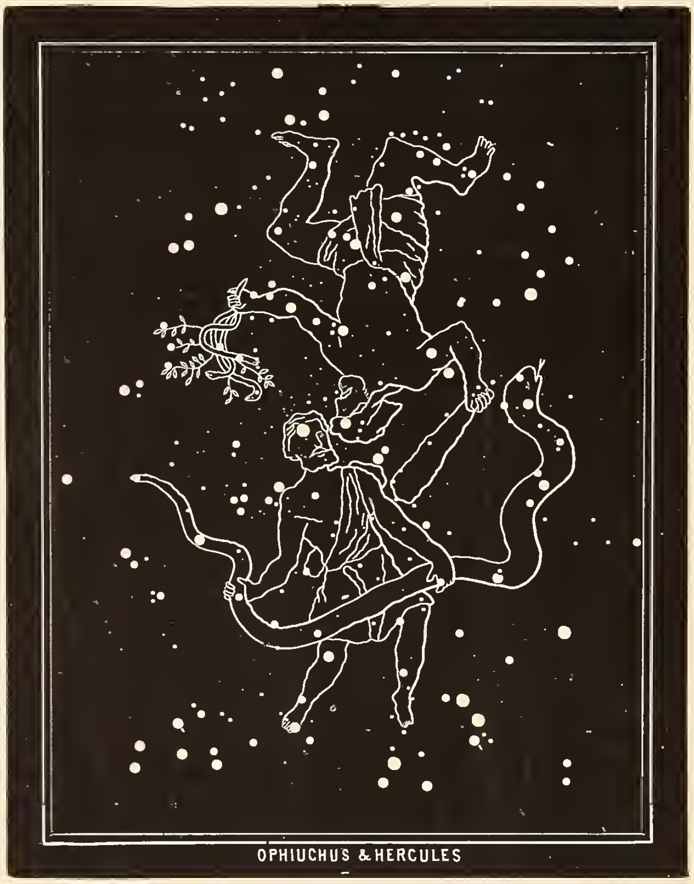


FIG. 2. OPHIUCHUS AND HERCULES.

We have shown that the zodiac must originally have been employed as a division of the solar year into twelve parts, the individual constellations representing, in all probability, the season of the year, the nature of the prevailing weather, or the principal occupation at the time when each group was in conjunction with the sun, or when the solar orb was passing amongst its stars. For the constellation figures do not seem to have been suggested by a resemblance of the various star groups to familiar objects, because in most cases they have no resemblance whatever to the object named, but each of the old groups was identified with objects typical of what was continually taking place either in the heavens or on the earth; in particular with the struggles, victories, and defeats of the "Great Sun God," in his encounter with the evil powers of darkness, while performing his annual journey round the star-sphere. If this, then, be the object for which the zodiac was invented, one would expect that its constellation figures would be strikingly representative of some particular country, and if of Egypt, they would be intimately connected with the Nile; for from the remotest antiquity Egypt has been considered as solely dependent on that great river, as, from the regular overflow of its water, this country is in reality the "Gift of the Nile." This the ancient Egyptians fully recognised. They said:—

---

* In the poem of Aratos this constellation is well described :—

"Like a toiling man, revolves
A form. Of it can no one clearly speak,
Nor to what toil he is attached ; but, simply,
Kneeler they call him. Labouring on his knees,
Like one who sinks he seems ; from both his shoulders
His arms are raised ; each stretching on its side
About a full arm's length. And his right foot
Is planted on the twisting serpent's head."

> "Hail to thee, O Nile:
> Thou showest thyself in this land,
> Coming in peace, giving life to Egypt."*

Egypt, then, without the Nile is nothing, for without the regular inundations, it would be like the immediately surrounding country, partly a sandy waste and partly a rocky desert, and could not in the past have played so important a part in the world's history as it has undoubtedly done. Only by the presence of the river flowing from the mysterious regions of the south was Egypt fertilised. Annually it conveyed to the multitudinous inhabitants dwelling on its banks, great agricultural wealth; produced a salubrious climate, and at the same time beautified the landscape. Therefore we would expect that, if the zodiac were an Egyptian invention, many of the constellations of which it is composed would be more or less directly connected with the yearly rise and fall of this great river. Indeed, this seems to be the case, for, when due allowance is made for the gyratory motion of the earth, or the precession of the equinoxes, the principal events which took place in ancient Egypt throughout the year, and their duration, are fully explained.

In ancient Egypt, the solar year is believed to have commenced with the lower, or winter solstice, which, though corresponding to our winter, was the time immediately following the sowing of the seed. At our spring, three months afterwards, when the sun was crossing the vernal equinox, the harvest took place, and this was followed by the valuing of the crop and the payment of tribute. During the two months preceding the summer, or higher solstice, the most unhealthy season and the greatest climatic disadvantages were experienced. For no less than fifty days, as is the case still, the *khamsin*,† or deadly south wind, prevailed, bringing with it disease and death; for if the plague appeared throughout the year it was during that interval. About the middle of our June, or near the time of the higher solstice, the Nile, in ordinary seasons, began to rise, and continued steadily to do so, till by the beginning of August the overflow occurred. Three months after the commencement of the rise, towards the end of September, at the time of the descending or autumnal equinox, the inundation reached its highest, when, according to Herodotus, the whole "Delta" was converted into an inland sea, whose towns and villages appeared dotting the surface like so many islands. From this time the fall rapidly took place, and in little over one month from the maximum overflow, or towards the close of October, the waters had so far subsided as to again be confined to their original channel, and once more the Nile appeared. The waters having now subsided, and having by their presence deposited a valuable coating of soil, thereby giving to the land a greater fertility than the richest manure could have imparted, the country was, during the next month—corresponding to our November—put under culture, and, by the second month of the year, or February, covered with green and luxuriant crops.

The above-mentioned events, which took place throughout the year in ancient Egypt, are fully explained by the zodiacal constellations, if we move them backwards to the apparent positions they occupied at the distant epoch of between fourteen and fifteen *thousand* years ago, or at the time when the brilliant star *Spica* was near the vernal equinox. To many this may appear as too far back to be accurate, yet no other epoch will explain the zodiacal calendar of ancient Egypt, and even a difference of only one thousand years either way makes a considerable alteration in the coincidences. At the distant epoch already mentioned, the constellations, owing to the precessional movement of the earth which has since taken place, were occupying a position in the sky nearly diametrically opposite to that in which they at present appear (*see Plate* 3). CAPRICORNUS, for example, instead of being where it now is, near the lower solstice, was then on the higher, or summer solstice; while CANCER, instead of occupying, as now, nearly the highest point in the ecliptic, was then situated at the lowest part of the sun's yearly course. The equinoctial constellations were reversed in a like manner—VIRGO occupying the vernal, and PISCES the autumnal equinox. The harvest, we have seen, being near the time of the sun's crossing the equator, when ascending, or in our spring, this luminary was thus, during the time of harvest, travelling among the stars of what has long been considered as a purely harvest constellation,—viz., VIRGO, the Virgin, who, as mentioned by Aratos, "carries in her hand the brilliant ear of corn" (the star *Spica, see Plate* 2). The next constellation, or LIBRA, though believed by many to be a more recent invention than the other zodiacal constellations, seems also to be intimately connected with the harvest, or the ingathering of the grain. This constellation figure has been explained by some as originally representative of justice, or as a sign of equality, invented at the time when it was situated on the autumnal equinox, when the days were equal to the nights, or when there was a balance of light and darkness. Others have even held that it is of very recent date, there being originally only eleven zodiacal constellations. There is evidence, however, that such is not the case, but that it is as ancient as the others, and, coming as it does immediately after the "Gleaning Maid," the constellation of the Balance seems more reasonably to be representative of what undoubtedly then took place during the time the sun was passing through the stars composing it—viz., the balancing month—the month in which the grain was weighed and valued, when the amount for tribute or tithes was probably laid aside.

---

* "Hail to thee, O Nile:
Thou showest thyself in this land,
Coming in peace, giving life to Egypt.

* * * *

O inundation of Nile, offerings are made to thee;
Oxen are slain to thee;
Great festivals are kept for thee;
Fowls are sacrificed to thee;
Beasts of the field are caught for thee;
Pure flames are offered to thee;
Offerings are made to every god,
As they are made unto Nile.

* * * *

Shine forth, shine forth, O Nile! shine forth!
Giving life to men by his omen;
Giving life to his oxen by his pastures!
Shine forth in glory, O Nile!"

See Rawlinson's "Egypt."

† *Khamsin* is an Arabic word meaning fifty.

After LIBRA come the constellations of SCORPIO and SAGITTARIUS—constellations which fully explain what took place during the two months preceding the summer solstice. As the sun at that distant time entered the scorpion's claws, his long struggle would commence with what to the Egyptians would be the power of evil. At this very time the fatal winds began to blow from the south, bringing with them death and destruction. The sun, at intervals shorn of his beams, and often nearly obscured by the amount of fine sand blown from the desert, had the appearance of struggling with the powers of darkness. The god of the river, too, would seem to have withdrawn his beneficent power, as the waters of the Nile were then at their lowest. SCORPIO, then, which has always been considered as symbolical of evil and darkness, the constellation that was considered cursed by the ancients, would indeed be typical of the then prevailing power;* for the winds did not cease until the sun had passed from amongst its stars, and entered those of SAGITTARIUS, which very suggestively represents the solar hero, shooting his arrow, or his beams, at the scorpion's heart, and finally triumphing over the power of evil.† (*See Plate* 2).

From SAGITTARIUS, the sun, in his upward and triumphant course, would now enter the constellation of the Goat, or CAPRICORNUS, at the time when his highest point, the summer solstice, was reached. In the time of Eudoxos this constellation occupied nearly an opposite position, or was situated at the winter solstice, as Aratos mentions "where retrogrades the solar might." With more truth, however, the words may be applied to the position in which it was placed at the distant epoch already mentioned, for is it not certainly a climbing

---

[*] The Akkadian word for this constellation means "the Seizer-and-Stinger," and also "The-Place-where-one-bows-down," both of which meanings clearly indicate the supposed nature of, and effect produced by, the constellation.

[†] In the cuneiform inscriptions Sagittarius is designated "the Strong one," the "Giant king of war," and the "Illuminator of the great city"; titles which are strikingly representative of the sun when overcoming evil, or darkness.

animal, grazing not in the lowland regions, but in the rocky heights of the mountains? Accordingly the original position of CAPRICORNUS could not have been where it now is, near the *lowest* part of the sun's apparent annual course, but at the position it occupied fifteen thousand years ago—viz., the higher solstice, representing the sun as having reached his highest point in the heavens. In examining the constellation figure on Plate 2, it will be noticed that the celestial animal is totally unlike a true capricorn, in respect to its having a *fish's* tail. This is no comparatively modern addition, as it is not only given on a MS. in the British Museum, supposed to belong to the second century of our era (*see Fig.* 3), but the amphibious nature of the creature has been discovered on an excavated Babylonian stone.* The meaning of this rather curious appendage has not, as far as I am aware, been suggested by any previous writer. The explanation, however, seems to be a very simple one when we consider the position the constellation occupied at the time mentioned. At that time the stars forming the fish's tail of the goat, marked the sun's position at the exact instant *the Nile began to rise,* when the sun was beginning to descend from the highest point, and, as a deity, to exert his mighty influence on behalf of the rising waters.† This supposition is remarkably borne out by the next constellation, or AQUARIUS, the Water-Bearer—which, as will be seen in Plate 2, overlaps to a large extent the fish's tail. This constellation, like the others previously noted, is also typical of the principal event which took place in ancient Egypt.‡ As the sun advanced into the constellation of the Water-God (AQUARIUS), its influence produced the steady rise of the river, until by the time he had reached that part of his course which is marked by the stars representing the mouth of the vessel from which Aquarius pours out the water, the Nile had, in ordinary seasons, risen to such a height that its waters were literally "poured out over the land." This is no idle imagination, but an actual fact, which undoubtedly took place in Egypt at the time we mention, and the surrounding constellations, instead of contradicting the hypothesis, only lend their aid to confirm it in a striking manner. Near AQUARIUS, for instance, is the Southern Fish, swimming in the stream, and the dreaded "sea monster" (CETUS), plunging in the now really "deep waters"; while the next zodiacal constellation, PISCES, is symbolical indeed of the season, when, owing to the complete flooding of the land, fish would be easily and plentifully obtained.

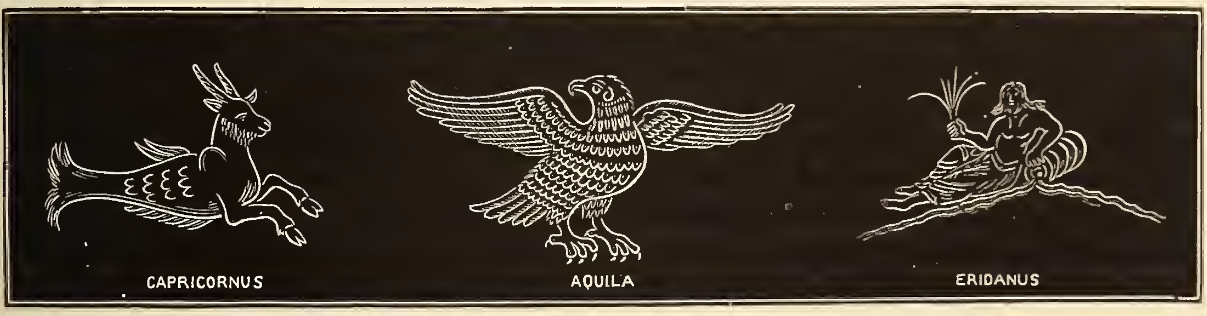


FIG. 3.—CONSTELLATION FIGURES IN AN MS. OF THE SECOND CENTURY A.D.

At this time, as already mentioned, PISCES embraced the autumnal equinox, extending exactly to the position which the sun reached when the inundation was greatest. From this moment, as the sun pursued his zodiacal course, the waters began rapidly to retire, and in less than one month afterwards, or by the time the sun had passed through the constellation of Aries, the water had subsided to so great an extent that sheep and other animals could once more in safety be sent out to pasture—when probably a ram, as representative of the leader of the flock, was sacrificed.* The sun, too, when in this position, was directly over the end of the long winding constellation, ERIDANUS, the River, which in all probability represents a duplication of the Water-God, if not of the Nile itself (*see Fig.* 3); for, when the sun was in this position, the Nile, which for nearly three months had been lost in the flood, had now so far regained its original channel as to be once more visible. Above Aries, too, is the very old constellation of the Triangles, which has always been connected with the Delta of the Nile; and with good reason, for the sun was in conjunction with the Triangles when the various land-marks destroyed by the inundation would require to be renewed, or the land triangulated and measured, from which necessity, in all probability, originated the science of geometry.

---

* According to Prof. Sayce the Euphratean name, found on the cuneiform inscriptions for the month occupied by Capricornus, is the "Father of Light," and he remarks, "It is difficult to understand how it can have been called a month of light." This, however, is fully explained by the position occupied by the constellation as above indicated. Whilst the sun, as already mentioned, was traversing the constellation of the Goat, the days were longest and illuminated to the fullest extent, so that this period was truly a "month of light," which it could not have been at any other epoch than that of about 15,000 years ago.

† The Egyptian god of the waters, "Chnum" is, curiously enough, represented with *goat's horns* (not ram's horns)—thus showing the intimate connection between CAPRICORNUS and the rising of the Nile.

‡ The Akkadian meaning for the month occupied by Aquarius is "The Lord of Canals." As revealed by the brick tablets, the constellation is also intimately connected with the Deluge.

The sun now entered the constellation of TAURUS, and continued there during the month corresponding to our November, which, in ancient Egypt, was the month when the land was put under cultivation, and the oxen yoked to the plough. In this constellation is the well-known and very ancient group called the PLEIADES, mentioned by Aratos as the Clusterers. These always seem to have been intimately connected with agriculture.† From TAURUS, the sun next passed into the constellation of GEMINI, the Castor and Pollux of the Greeks, but mentioned in Aratos only as the Twins, and known to the ancient Egyptians simply as a pair of kids, to the Chaldeans as a pair of gazelles, and to the Arabians as a pair of peacocks. This, in all probability, at the epoch we refer to, marked the lambing season, and AURIGA seems to be in some way connected, as the figure of the so-called charioteer has always been represented as holding kids in his arms.‡

In moving out of GEMINI, the solar orb next entered the dark and gloomy constellation of CANCER, the Crab—which, from its faint stars and dark appearance, was very anciently looked upon as typical of the powers of darkness. Like nearly all the constellations in the heavens, CANCER bears no resemblance whatever to the object it is supposed to represent, but received its character simply from what usually took place, either on the earth or in the heavens, when the sun moved among its stars. Hitherto it has been supposed by many that at the time CANCER received its name, it occupied the place of the higher solstice, for, as crabs appear to walk backwards, this creature was thought very fitly to indicate that part of the sky where the solar retrogradation occurred! This, however, would only give an epoch of little more than two thousand years ago, a date, undoubtedly, too recent, and quite within historic times. But the constellation of CANCER is far older, and was evidently known to the Egyptians in very ancient times. The Egyptians, as is well known, do not seem to have been very familiar with the crab, but they had a creature somewhat similar, and to them vastly more important—the celebrated Scarabaeus, an insect of the beetle species.§ By them this creature was treated with the greatest reverence, as is shown in the Temple of Edfou, where there is to be seen sculptured on the walls priests paying Divine honours to it, as symbolical of the sun. What, then, would be more natural than that it should occupy a prominent position in the celestial calendar of a people in whose eyes it was exceedingly sacred? At that epoch already mentioned the constellation of the Scarabaeus (CANCER) would indeed occupy the most prominent position in the Egyptian zodiac! It would mark, indeed, the lowest, and most critical part of the sun's apparent yearly path (*see Plate* 3).* For when the sun entered this dark constellation, the days would not only be shortest, but the fight with darkness greatest. Was their god, whose presence brought life and happiness, intending to sink lower in the heavens, and leave them altogether? would be the anxious question of the ignorant and superstitious masses of a sun-worshipping nation; or would he, after reaching his lowest point, begin once again to mount upwards, and for another year repeat his encounters with the powers of evil? Now, to the Egyptians the Scarabaeus was not only a very sacred creature, but at the same time a creature representative of the resurrection, or the continuance of life. So that they had very appropriately indicated their first month of the year by placing in the heavens the sign of continued life, exactly in the position where their sun-god moved when his struggles for the time were over, and his power restored, as it were, by beginning the ascent into the heavens.

---

* The Assyrian word for the month occupied by Aries is the "Altar" and the "Sacrifice."

† "The Flock of Clusterers. Not a mighty space
Holds all, and they themselves are dim to see.
And seven paths aloft men say they take,
Yet six alone are viewed by mortal eyes.
From Zeus' abode no star unknown is lost
Since first from birth we heard, but thus the
tale is told;
These seven are called by name Alkyone,
Kelaino, Merope, and Sterope,
Seygete, Elektre, Maia Queen.
They thus together, small and faint, roll on,
Yet notable at morn and eve through Zeus,
Who bade them show when winter first begins,
And summer, and the season of the plough."

‡ Gemini may also have been connected with the birth of a new year, which was supposed to be brought about by the influence of the twin deities, the Sun and Moon.

§ In a MS. of the twelfth century the constellation figure of Cancer is represented by a creature somewhat like a *water-beetle.*

After CANCER comes the last of the twelve zodiacal constellations we have to mention—LEO, the Lion. That this constellation should occupy the position it does in the zodiac is not at once so clear, as the lion does not specially belong to Egypt. But though this is the case, it is certainly African, and was therefore not unknown to the ancient inhabitants of the Nile Valley. It was perhaps owing to its rarity that it came to be looked upon as a somewhat sacred animal, and introduced into the zodiac, to which the Sphinx, a purely Egyptian conception, seems to testify; the Sphinx being simply a combination of two constellation figures, *Virgo* and *Leo*, and likely to have been invented at about this epoch, as these constellations then occupied the most important part of the ancient star sphere, the vernal equinox.† When the sun, then, was moving through LEO, the crops were beginning to ripen, and the solar hero of the Egyptians was once more appearing in all his strength and power, like a lion, as he approached the equinox ascendingly—that triumphal crossing point which divided the celestial sphere of the ancients into the two important hemispheres—the lower, a region of death and darkness; the higher, a region of life and light.‡ Thus, LEO is in all probability but another type of the sun; the sun in all his strength, which like a lion is prepared to spring on HYDRA, the Great Water-Snake, beneath—symbolical, again, of the power of darkness. The most vital portion of the latter creature, the head, has been well placed, where the struggle was fiercest—*i.e.*, when at the lowest part of his course, or under the constellation of the Crab (*see Plates* 1 and 2). When, however, the sun climbed into Leo, the triumph commenced, and by the time he had reached that part of his path which lies directly above the tail of Hydra, the victory was accomplished, the great orb had crossed the Equator, and travelled into the region of light! Such, then, were the struggles which the solar deity of the ancient Egyptians had to encounter in his yearly movement round the star sphere. The seemingly meaningless constellations of the zodiac are thus, in the most natural manner, fully accounted for.

As already suggested, many of the ultra-zodiacal constellations seem to be duplications of those composing the zodiac. For example, immediately above SCORPIO and SAGITTARIUS, as representative of the sun's struggle with the evil power, is OPHIUCHUS and SERPENS—the Serpent-Bearer and the Serpent—which is very evidently symbolical of the solar hero, standing upright and triumphant, firmly holding the vanquished though still struggling serpent—the ancient representative of evil (*see Fig.* 2). The same idea is again brought out in the constellations lying directly underneath, or to the south of SCORPIO—in CENTAURUS, a solar hero, and LUPUS, a type of darkness—the latter, however, being a comparatively modern name for an ancient and similar character.

The harvest constellation of the Virgin seems also to be duplicated, for above it is BOÖTES, the Ploughman, or rather harvester, symbolical of the harvest, which was being reaped during the time of the sun's passage beneath the constellation. AQUILA, again, one of the very old constellations, being placed above CAPRICORNUS, would, at the epoch mentioned, be situated directly above the higher solstitial point, and be symbolical of the sun's highest flight.* This is strikingly corroborated by the old drawings of this constellation figure, which, instead of showing the eagle flying downwards, as in Plate 1, indicates the celestial bird sitting upright, and apparently perched on some high mountain peak (*see Fig.* 3), at once suggesting the idea that it is representative of the sun having reached his highest point in the heavens. Following AQUILA is the small, though very ancient constellation of DELPHINUS. This constellation being situated immediately after the higher solstice, very fitly indicates the direction of the descending course of the sun; which, like a dolphin having ascended, will now descend, or re-plunge beneath the wave. In ERIDANUS, as already indicated, we have, in all probability, a duplication of AQUARIUS, the Water-God, as representative of the Nile; in CETUS and PERSEUS, another fight between the powers of light and darkness; and in the young goats, in the constellation of AURIGA above GEMINI, a duplication of the zodiacal constellation of the twin kids. The brilliant star *Sirius* (CANIS MAJOR) and the magnificent constellation of ORION, seem also to have been used at the date already mentioned. *Sirius*, the "Blazing Dog-Star" is known to have always been intimately connected with the Nile. The position it occupied at that date was such that its appearance announced the rising of the river; and thus it was symbolical of a faithful dog warning the Egyptians to be on their guard. But its use did not stop here, for, by its regular appearance, the length of the old Egyptian year was determined.

---

* The original position of Cancer, near the lower, or southern solstice, is clearly proved by the meaning of the Akkadian word for the month occupied by the constellation—viz., "The Sun of the South" or the "Southern Sun."

† The Egyptian goddess "Sechet" or "Pasht" appears simply to be the Sphinx, as she is always represented with a lion's head. The connection between the Sphinx (Leo and Virgo) and Hydra is indicated by the goddess having the sun's disc and snake on her head.

‡ According to Macrobius "This beast seems to derive his own nature from that luminary (the Sun), being in force and heat as superior to all other animals, as the sun is to the stars. The lion is always seen with his eyes wide open and full of fire, so does the sun look upon the earth with open and fiery eye."

The above appear to be the principal ultra-zodiacal constellations connected with the epoch of about 15,000 years ago. Several of the others are probably quite as ancient, but, on the other hand, may have been of comparatively recent date. In fact, one could scarcely expect that even the principal groups, outside of the zodiac, would receive names and characters at the same time, but that the completion of dividing the visible star-sphere into constellation figures would be the result of the studies of several generations. Indeed, there is evidence that several of the constellation figures were invented at the epoch of only 4000 years ago, and in a latitude slightly different from that of Egypt; but those that have been mentioned, from their positions in the heavens, seem to have been known long before that time in the region of the Nile, or to the ancient Egyptians.

Of course it may be urged that the same coincidence took place at a much more recent date, when the sun, instead of being in *conjunction* with the star group, was exactly opposite to it, or when the group was seen high on the meridian at midnight. This would certainly be the case after one half of a precessional revolution, 13,000 years later, or 2000 years ago. From historic evidence alone, however, this date is known to be far too recent; besides, as is well known, the ancients never followed this method. A star, or constellation, was supposed to have power only for good, or evil, when its influence was *added* to that of the solar orb, not when in opposition to the sun, or seen in the heavens at midnight. Astrologers regarded the star groups in the same way, so there is every reason to believe in the more remote date, distant though it is, as having been the time when many of the constellation figures were invented by the highly civilised, and certainly the most remarkable people the world has seen—the ancient inhabitants of the Nile Valley.

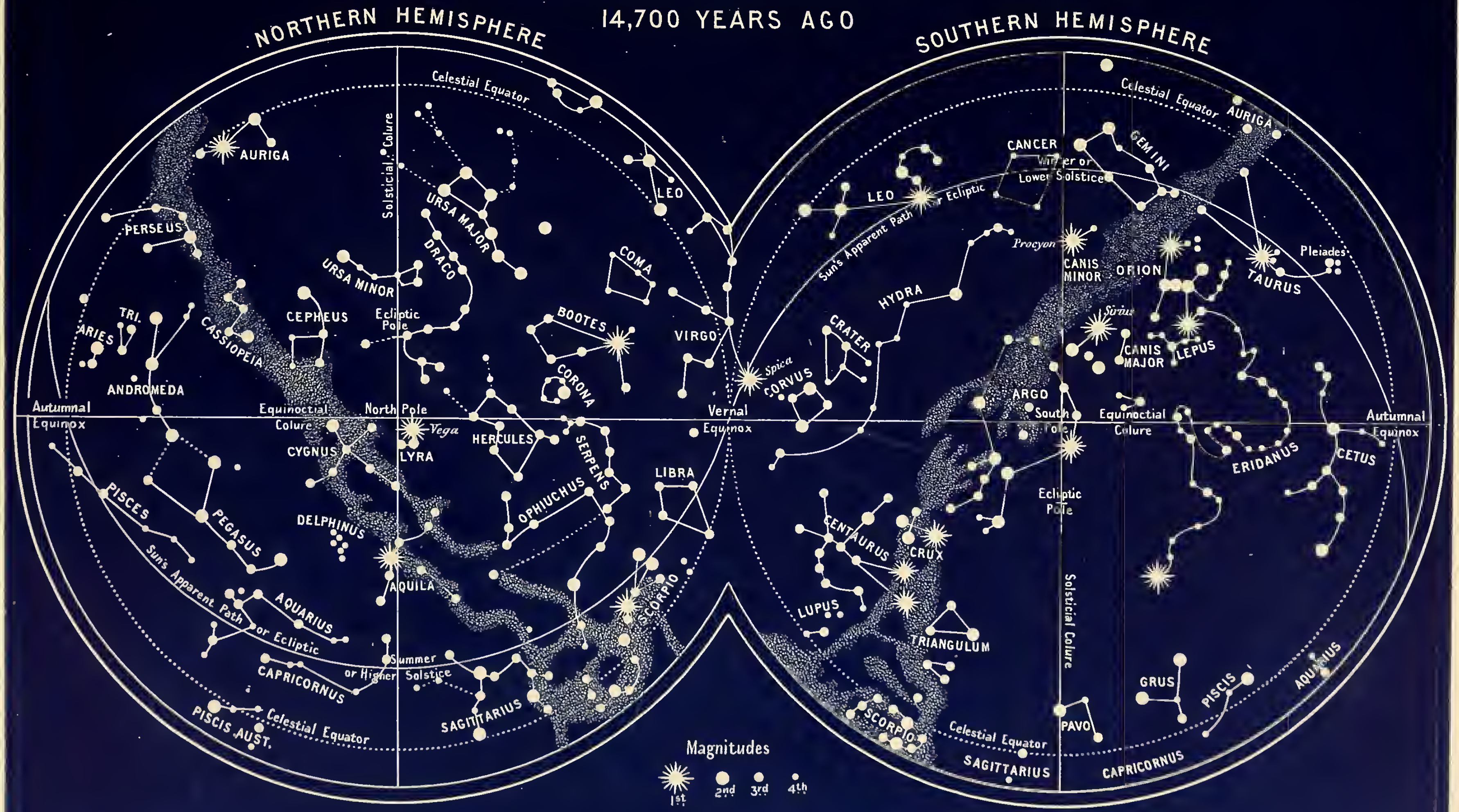
---

* The ancient Egyptians considered the hawk as sacred, and symbolical of the sun. Their sun god Horus, the son of Osiris, is always represented with an *eagle's head*, surmounted by the sun's disc; and in the Egyptian temples the deity's omnipresence is symbolised by outspread eagle's wings.

PLATE 3.

THE POSITION OF THE CONSTELLATIONS

14,700 YEARS AGO



NORTHERN HEMISPHERE

SOUTHERN HEMISPHERE

Celestial Equator
Solsticial Colure
AURIGA
LEO
PERSEUS
URSA MAJOR
DRACO
URSA MINOR
COMA
TRI.
ARIES
CASSIOPEIA
CEPHEUS
Ecliptic Pole
BOOTES
VIRGO
ANDROMEDA
CORONA
Autumnal Equinox
Equinoctial Colure
North Pole
Vega
LYRA
HERCULES
SERPENS
Vernal Equinox
CYGNUS
LIBRA
PISCES
PEGASUS
DELPHINUS
OPHIUCHUS
SCORPIO
Sun's Apparent Path or Ecliptic
AQUILA
AQUARIUS
Summer or Higher Solstice
CAPRICORNUS
SAGITTARIUS
PISCIS AUST.
Celestial Equator
Magnitudes
1st
2nd
3rd
4th
CANCER
Winter or Lower Solstice
GEMINI
AURIGA
LEO
Ecliptic
Suns Apparent Path
Procyon
CANIS MINOR
ORION
Pleiades
TAURUS
HYDRA
Sirius
CRATER
CANIS MAJOR
LEPUS
Spica
CORVUS
ARGO
South Pole
Equinoctial Colure
Autumnal Equinox
ERIDANUS
CETUS
Ecliptic Pole
CENTAURUS
CRUX
LUPUS
TRIANGULUM
Solsticial Colure
AQUARIUS
GRUS
PISCIS
PAVO
SCORPIO
Celestial Equator
SAGITTARIUS
CAPRICORNUS

Constructed by W. Peck Edinburgh

CHAPTER II.

MOVEMENTS OF THE EARTH WHICH AFFECT THE APPEARANCE OF THE HEAVENS.

> "The planet Earth so stedfast though she seem,
> Insensibly three different motions move."—*Milton.*

DIURNAL MOTION.

The least attentive observer cannot fail to have noticed that during each day every celestial object appears above the eastern portion of the horizon, mounting into the sky until it reaches its highest point on the meridian, then gradually sinking and approaching the horizon, where finally it disappears towards the west. This is owing to the well-known apparent *diurnal,* or daily movement of the star-sphere from east to west, produced by the rotation of the earth on her axis in the opposite direction. During each interval of 23 hours 56 minutes 4 seconds our globe makes a complete rotation, and turns the observer successively towards every celestial object. All bodies on the celestial sphere thus appear above his horizon, and move in a westerly direction, describing, throughout a complete revolution, true circles round two apparently fixed points in the heavens, which are directly above the poles of our globe.

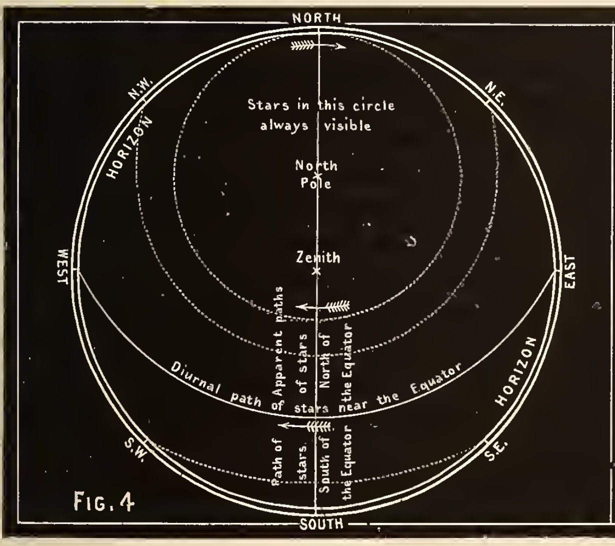

NORTH
N.W.
HORIZON
N.E.
Stars in this circle always visible
North Pole
Zenith
WEST
EAST
Apparent paths of stars North of the Equator
Diurnal path of stars near the Equator
HORIZON
S.W.
S.E.
Path of stars South of the Equator
SOUTH
FIG. 4

Fig. 4. Diagram showing paths of stars on the star sphere for latitude 50°.

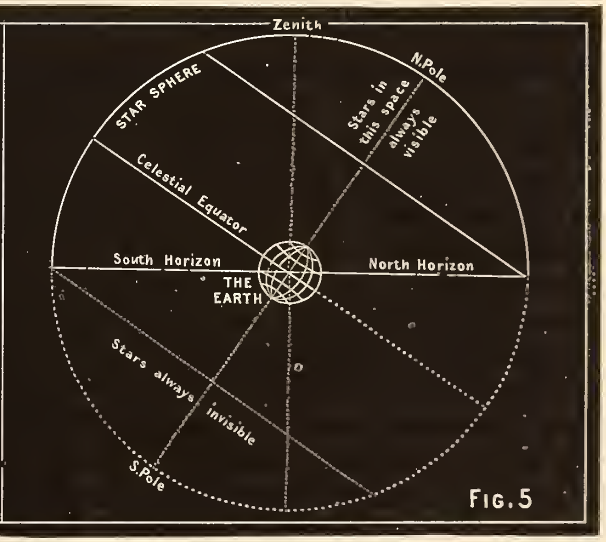

Zenith
N.Pole
STAR SPHERE
Stars in this space always visible
Celestial Equator
South Horizon
North Horizon
THE EARTH
Stars always invisible
S.Pole
FIG. 5

Fig. 5. Diagram showing stars visible and invisible for latitude 50°.

Each object, however, does not pursue the same apparent diurnal path. Those, for instance, situated midway between the poles of the heavens or near the celestial equator, rise exactly in the east, and set due west. All objects, on the other hand, south of the equator, rise, in proportion to their distance from that great circle of the heavens, to the south of the east, and set to the south of the west; and those to the north, rise and set at places on the horizon from the east and west also in proportion to their positions with respect to the equator (*see Figure* 4). All stars whose distances from the pole elevated above the horizon of the observer are less than his distance, in degrees, from the terrestrial equator, never set at all, but are always above the horizon, and become visible shortly after sunset; while those situated within the same distance from the opposite or depressed pole never rise, and are in consequence always invisible. Thus in Britain all stars whose distances from the North Pole are less than 52 degrees, as in Figure 5, never set, but apparently revolve round the Pole in a direction opposite to that of the movement of the hands of a watch; while, on the contrary, those stars distant from the South Pole less than 52 degrees are never seen in Britain, being constantly beneath the southern horizon (*see Fig.* 5).

From the apparent diurnal movement of the star-sphere, the appearance of the heavens is constantly altering. Star-group after star-group is caused to disappear in the west, while in the opposite part of the sky, towards the east, new groups are brought into view; and thus a constellation that appears high up in the sky will, a few hours afterwards, be low down on the western horizon, or have entirely disappeared.

ANNUAL MOTION.

But while the stars are apparently carried daily round our globe as a centre, they seem also to travel round once every year. Each day if a particular group of stars be watched, it will be found that it rises and sets sooner than on the previous day, thus apparently moving towards the west, until it gets lost in the sun's rays. A constellation, for example, that on a particular day is seen near the meridian at midnight, will, three months afterwards, be seen in the same position six hours earlier; six months afterwards, twelve hours sooner; nine months afterwards, eighteen hours sooner; and in the course of a year be again on the meridian at midnight. This apparent movement, to which all stars are subjected, is the outcome of the earth's annual journey round the sun. From this revolution of our globe, the sun is apparently caused to move among the stars to the east, thus producing an apparent forward movement of the constellations to the west, or towards the sun. Now, as our day, or time, is determined by the return of the sun, he thus seems to be stationary, while the stars are apparently carried round the earth once every year, or exactly in the time occupied by our globe in making a complete revolution of its orbit. The stars, then, occupy positions in the sky with respect to the sun, depending on the position of the earth in her orbit, or on the season of the year. This is why some constellations are seen only at certain seasons, for a group of stars can only be visible when somewhat distant from the sun, so as to appear above the horizon before sunrise or after sunset. The zodiacal constellation of GEMINI, for instance, cannot be seen at the beginning of July, for the sun is then directly between us and the group; but the zodiacal constellation that is diametrically opposite to it—SAGITTARIUS--will be on the meridian at midnight, a position that the TWINS cannot occupy till the beginning of January, when the sun is then apparently moving among the stars of the ARCHER. Therefore while the diurnal rotation of the earth is turning the observer to different parts of the star-sphere, and constantly altering the appearance of the heavens from hour to hour, the annual movement of our globe round the sun is changing the aspect of the heavens from day to day at the *same* hour. For the purpose of easily following these two important apparent motions from any part of the globe, the twenty-four different views or circular maps, inserted at the end of the volume, have been constructed.

GYRATORY MOTION, OR PRECESSION.

The diurnal and annual motions are the two principal apparent movements of the star-groups, and were known from very ancient times. There is, however, another motion of the earth sensibly affecting the appearance of the heavens, which was not discovered till about the year 120 B.C. Hipparchus, by comparing his own observations of the positions of the stars with those made 180 years previously by Timocharis, discovered that they were slowly travelling round the celestial sphere in paths, which, unlike those described by the stars in the daily and yearly movements, were not parallel to the equator, but to the track traced out by the apparent annual movement of the sun, and in the same direction. This is now known as the Precession of the Equinoxes, first truly explained by Copernicus, and physically accounted for by Newton, as being produced by the attractive action of the sun and moon on the spheroidal figure of the earth in endeavouring to cause the terrestrial equator to coincide with their own, the ecliptic plane. This action causes the equinoctial points, or those places where the equator crosses the sun's apparent annual path—places occupied by the sun every 20th of March, and 22nd of September—to slowly proceed, or move along the ecliptic, from east to west, which produces an apparent movement of the stars round the ecliptic in an opposite direction. From the same cause the poles of our globe do not constantly point to the same part of the heavens, but describe circles round those points perpendicular to the plane or level of the earth's orbit, or the poles of the ecliptic, in a period of about twenty-six thousand years. Now, as the poles of the earth are inclined from the vertical to the orbit, or from the poles of the ecliptic, about 23½ degrees, the circles they apparently describe on the star-sphere during each precessional period, have each a diameter of 47 degrees, as represented in Figure 6 Accordingly the brightest star in the constellation of URSA MINOR—*Polaris*—has not always occupied its present position with respect to the North Pole of our globe. In the time of Hipparchus, for instance, the northern axis of the earth was directed to a point in the star-sphere distant from *Polaris* no less than *twelve* degrees, or twenty-four moon breadths. At present the distance between this star and the Pole is about one degree and a quarter, but 200 years hence, at the time of its nearest approach to the star, the distance will be less than one-half of a degree; while 11,500 years hence the Pole will be pointing about 47 degrees from *Polaris*, and be directed only about 4½ degrees from the star *Vega* in LYRA—by far the brightest star to which the North Pole is directed throughout the precessional period of twenty-six thousand years.

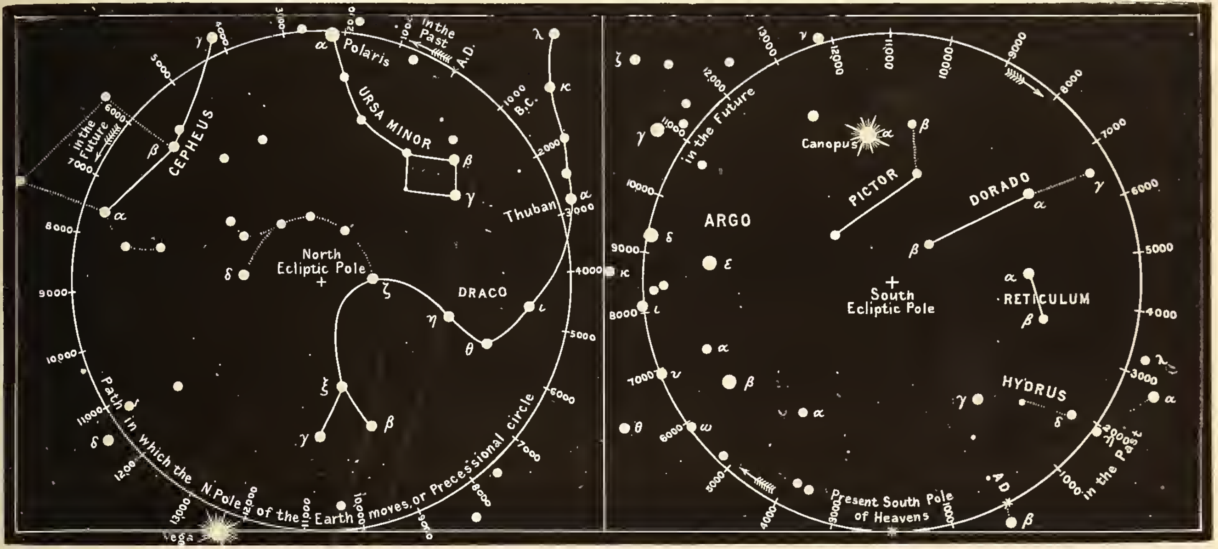


FIG. 6. DIAGRAM SHOWING PATH TRACED OUT BY THE EARTH'S AXIS OWING TO THE PRECESSION OF THE EQUINOXES.

It is this gyratory movement of the earth which has produced so great an alteration in the positions of the constellations as viewed from different parts of the earth, thereby furnishing the means for arriving at the probable epoch when many of the figures were invented. The zodiacal constellations, for instance, were at the time of Hipparchus more than thirty degrees, or a whole sign, to the west of their present apparent positions. Since then, the crossing-points of the equator and the ecliptic, from which the positions of the stars are determined,[*] have been carried along the ecliptic to that extent. This is why the twelve signs of the zodiac do not now coincide with the constellations from which they received their names. Before Hipparchus' time the zodiacal star-groups alone were used to mark off the various parts of the sun's yearly course; but about his date astronomy was becoming a more exact science than hitherto, and a more accurate method

ANCIENT AND MODERN POSITIONS OF STARS.

NAME OF STAR.	150 A.D. POSITIONS FROM OBSERVATIONS BY PTOLEMY.			1890 A.D. TRUE POSITIONS.		
	SITUATED IN *SIGN OF THE ZODIAC.*	*LONGITUDE.*	*LATITUDE.*	SITUATED IN *SIGN OF THE ZODIAC.*	*LONGITUDE.*	*LATITUDE.*
Aldebaran . .	[†]1 (Aries)	12° 20′	5° 10′ S.	2 (Taurus)	8° 15′	5° 29′ S.
Rigel . . .	1 „	20° 50′	31° 30′ S.	2 „	15° 18′	31° 9′ S.
Capella . .	1 „	25° 0′	22° 30′ N.	2 „	20° 20′	22° 52′ N.
Betelgeux . .	2 (Taurus)	2° 0′	17° 0′ S.	2 „	27° 13′	16° 4′ S.
Sirius . .	2 „	17° 40′	39° 10′ S.	3 (Gemini)	12° 37′	39° 32′ S.
Castor . .	2 „	23° 20′	9° 30′ N.	3 „	18° 43′	10° 4′ N.
Pollux . .	2 „	26° 20′	6° 15′ N.	3 „	21° 43′	6° 40′ N.
Procyon . .	2 „	29° 30′	16° 10′ S.	3 „	24° 19′	15° 58′ S.
Regulus . .	4 (Cancer)	2° 30′	0° 10′ N.	4 (Cancer)	28° 19′	0° 28′ N.
Spica . .	5 (Leo)	26° 20′	2° 0′ S.	6 (Virgo)	22° 19′	2° 2′ S.
Arcturus . .	5 „	27° 0′	31° 30′ N.	6 „	22° 42′	30° 57′ N.
Antares . .	7 (Libra)	12° 20′	4° 0′ S.	8 (Scorpio)	8° 14′	4° 33′ S.
Vega . . .	8 (Scorpio)	17° 20′	62° 0′ N.	9 (Sagittarius)	13° 46′	61° 46′ N.

was necessary for indicating the position of the sun in the ecliptic. Accordingly the ecliptic was divided into twelve *exactly* equal spaces or signs, and each sign into thirty spaces or degrees, each smaller division thus approximately marking the amount of apparent solar motion in a day. The first sign commenced with the vernal, or ascending equinox, the place occupied by the sun on the 20th of March when crossing the celestial equator in his journey northwards. At that time the constellation of the Ram occupied this position, so that the first sign was called Aries. In like manner the second, which was then occupied by the constellation of the Bull, received the name of Taurus, the third Cancer, &c.[‡] The equinoctial points, however, as already mentioned, are not fixed, but, by the gyratory movement of the earth, carried completely round the ecliptic once every twenty-six thousand years, and the signs accordingly have moved away from the constellations from which they were designated at the beginning of our era, or the zodiacal star-groups have apparently travelled along the ecliptic to the *west* of the places they then occupied. At present the constellation of ARIES is in the sign of TAURUS, the constellation of TAURUS in the sign of CANCER, &c. The stars in other parts of the heavens have likewise apparently been displaced. Those, for example, to the north of the vernal equinox, are apparently being carried slantingly away from the equator, and those to the south caused to approach it, thus altering their declination as well as their right ascension. At the autumnal equinox exactly the opposite effect takes place; while near the solstices (*see Plate* 3) the stars appear simply to drift to the eastward in paths nearly parallel to the equator, their right ascensions only being altered. The stars are thus apparently carried round the poles of the ecliptic in paths exactly parallel to the earth's orbit. Therefore, while their longitudes, or distances from the "first point of Aries," measured on the ecliptic, are altered, their latitudes, or distances north or south of the ecliptic, always remain the same, as will be seen from the Table given on the opposite page.

---

[*] The position of any heavenly body is determined by its angular distance north and south of the equator (called the declination), or by its distance north and south of the ecliptic or the sun's apparent annual path (called the latitude); and by its easterly distance from the vernal equinoctical point measured on the *equator* (called the *Right Ascension*), or by its easterly distance from the same point measured on the *ecliptic* (called the longitude). Thus the position of a heavenly body with respect to the poles and the equator of the earth is determined by its declination and Right Ascension; and its position with respect to the ecliptic by its latitude and longitude.

[†] Each sign is equal to 30 degrees of longitude.

[‡] The signs are indicated as follows:— ♈ Aries; ♉ Taurus; ♊ Gemini; ♋ Cancer; ♌ Leo; ♍ Virgo; ♎ Libra; ♏ Scorpio; ♐ Sagittarius; ♑ Capricornus; ♒ Aquarius; ♓ Pisces.

The effect produced by this apparent movement of the heavens, owing to the precessional motion of the earth, is somewhat striking. In an interval of about thirteen thousand years, or one-half of the precessional period, the constellations apparently occupy diametrically opposite positions on the star-sphere. Those groups which, thirteen thousand years ago, were seen during the winter months, are now visible only during the summer; and many of the constellations which then appeared when on the meridian low down on the horizon, are at present situated in the sky at considerable altitudes (*see Plate* 3).

NUTATION.

While, however, the poles of the earth, as in the precessional movement, gyrate round a vertical to the orbit, they do not, as might be supposed, move in uniform circles, as represented in Figure 6. Owing to the continual variation of the combination of the forces of the sun and moon exerted on the spheroidal figure of the earth, the inclination of the axis varies slightly, as well as the velocity of its movement in the precessional circle. This causes the poles of our globe, in swaying round the poles of the ecliptic, to trace on the star sphere a wavy circle, as indicated in Fig. 7. In this movement the poles sway on either side of the circle A B to the extent of about nine seconds of arc, or by about the eighteen-thousandth part of the diameter of the precessional circle A B. Each wave occupies about $18\frac{2}{3}$ years, equal to a complete revolution of the nodes, or crossing points, of the lunar orbit and the ecliptic plane; so that in each precessional period of twenty-six thousand years, no less than 1400 waves are described by the poles of our globe. Like the precessional movement already mentioned, only the right ascensions, declinations, and longitudes of stars are affected by nutation; the latitudes remaining constant. This minute, wavy movement of the poles was discovered in the year 1728 by the telescopic researches of the astronomer Bradley, but its cause was not fully explained till the year 1747.

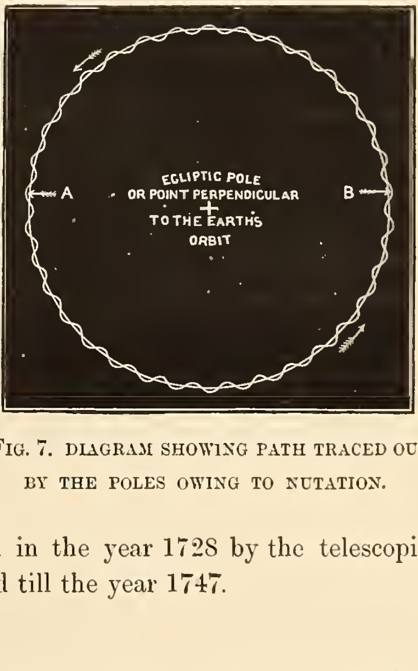


FIG. 7. DIAGRAM SHOWING PATH TRACED OUT BY THE POLES OWING TO NUTATION.

ABERRATION.

But the stars are subjected to still another apparent displacement,—one produced by the rapid motion of the earth in her orbit, combined with the sensible movement of light travelling to us from the stars. Our globe journeys yearly round the sun in a nearly circular path whose length is about 580 millions of miles, so that each second she travels over a space equal to about nineteen miles. Light, on the other hand, travels at the inconceivable velocity of about 186 *thousand* miles per second. Now, when the earth moves perpendicularly to the direction of a star, as at A, Fig. 8, the star will not appear as at S^1, but, owing to the earth's movement across the falling light-rays, in the direction of S^2—*i.e.*, the star is apparently thrown out of its true position in the heavens, in the same direction as that in which the earth moves; and the amount of displacement depends entirely on the proportion between the velocities of our globe and that of light. The same effect is produced when one walks in a shower of rain. If the drops fall perpendicularly, they will only appear to do so if the observer remain stationary, for whenever he moves the drops will appear to fall slantingly towards him, and the quicker his motion the greater the apparent inclination of the falling rain-drops. In the case of the light from the stars, the angular displacement, or the angle S^1 A S^2, is about twenty seconds of arc—a very minute quantity indeed, yet one easily perceptible to modern astronomical instruments.

Of course the displacement is greatest when the earth is in the position of A, with respect to a star, or moving nearly at right angles to the light-rays travelling from the star, which it does for each star at intervals of six months, or one-half of a revolution of her orbit. Three months before and after the earth moves perpendicularly to the star's light-rays, when travelling to or from the star, as at C and D, the aberration is at zero, and if the star be situated nearly on the same plane as the orbit of our globe, there will be no displacement whatever, while stars above and below the ecliptic level will be slightly displaced in a vertical direction. Thus throughout the year, each star, by the rapid moving of the earth, is caused apparently to describe a minute elliptical curve in the heavens, whose greater axis is 41″, or twice 20″·5 in length, and lies parallel to the ecliptic; while the smaller axis lies perpendicular to the orbit, and increases in dimensions as the ecliptic poles are approached.

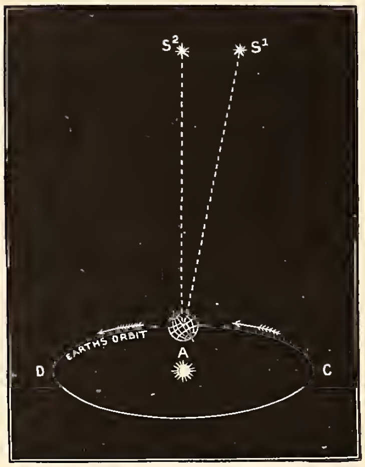


FIG. 8. DIAGRAM EXPLAINING ABERRATION OF LIGHT.

The displacement through aberration, which at first was thought to be the effect of parallax, was discovered by Hooke in the year 1669 from observations of the star γ in the constellation of Draco, a star which passes very near the zenith of London. It was not truly accounted for, however, till 1726, when Bradley, who was then thinking over the cause of the displacement, was accidentally led to the solution of the problem. One day, he happened to be crossing the Thames in a small boat, and by the strength of the current was unable to reach a certain part of the opposite bank at which he desired to land. Noticing that the amount of angular displacement in the water by the flowing stream depended on the velocities of the boat and the current, he was led to the true explanation of aberration—viz., the result of the combined velocities of the earth and light.

Proper Motion.

The different apparent movements to which every heavenly body is subjected from the real moving of the earth, are, therefore, the Diurnal, Annual, and Precessional rotations, and the Nutational and Aberrational displacements—all of which occur in regular periods. There are, however, other displacements which affect each star differently both in amount and direction. These, unlike the others above mentioned, are *real*, and are produced by the actual moving of the stars through space. They are called "proper motions" of the stars, and were first noticed by Halley in the year 1718. The stars are no longer considered as being *fixed*, for each is now known to be constantly changing its place in the heavens. The brilliant star *Arcturus*, for instance, has, since the beginning of our era, moved over a space on the star-sphere equal to two and a-half times the apparent diameter of the moon; while the well-known small star 61, in the constellation of Cygnus, moves so rapidly that in less than 300,000 years it will travel completely round the heavens. Fig. 9 indicates the comparative apparent angular displacements of several stars with large proper motions in ten thousand years' time.

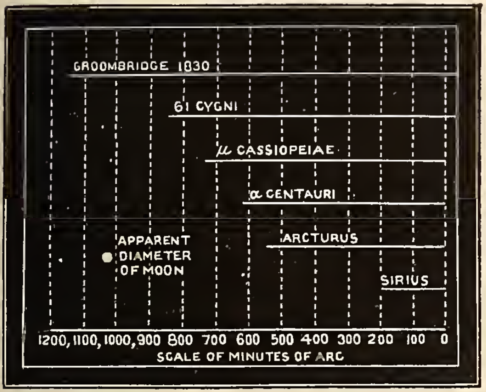


Fig. 9. Relative proportion of proper motion of stars.

The effect of this real movement of the stars is, after long intervals, to completely alter the appearance of the heavens, and to destroy the forms of many well-known constellation figures. Fig. 10 represents different views of three important groups after an interval of 100,000 years.

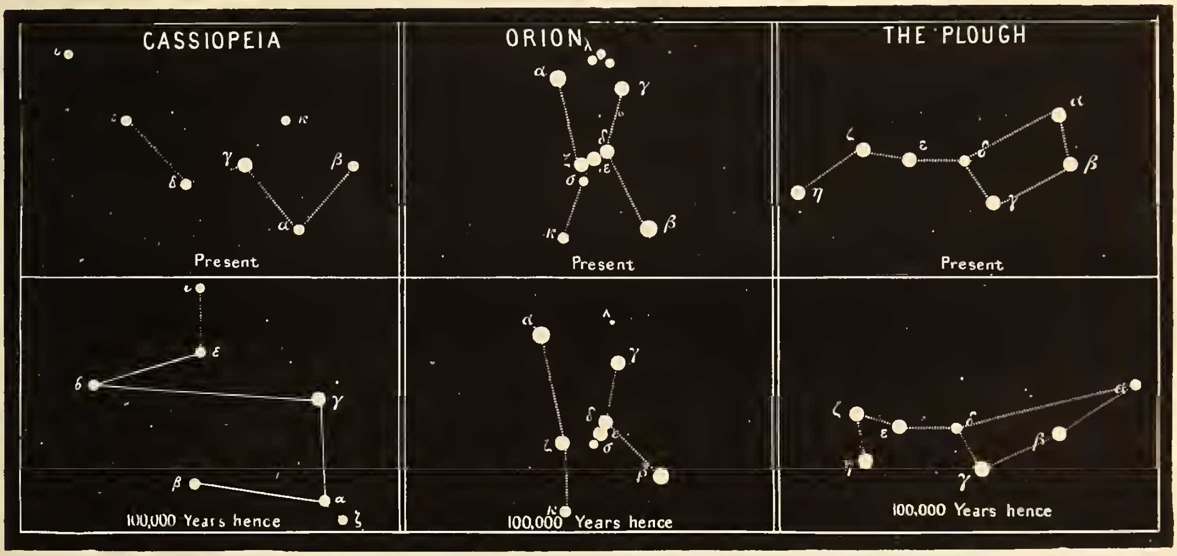


Fig. 10. Alterations in Appearance of some of the Constellations 100,000 years hence, owing to "Proper Motion."

In the proper motion, however, we do not see all of a star's movement through space. A star may appear fixed in the heavens, and yet it may be travelling to or from the earth or in the direction of the line of sight. If, then, this latter quantity be known, along with its distance, and the amount of proper, or apparent lateral, motion in the heavens, the velocity of the star's true movement in space can easily be computed. Thus, in Fig. 11, if A B represents the proper motion of a star, B C its movement in the line of sight, in this case towards the earth, A C will then be its true movement in space. Now, by means of the spectroscope, the velocity in the line B C can be determined; so that, knowing the distance of the star from our system, or E A, the actual velocity of the star in its journey through space, or A C, can be calculated. In many cases these velocities are very great indeed, being often as much as *one hundred* miles per second. Therefore, many of the stars, though apparently fixed in the sky, are in reality rushing through space at a velocity of over four times that of our earth in her orbital revolution, and two hundred times greater than the speed of a projectile from a rifled cannon.

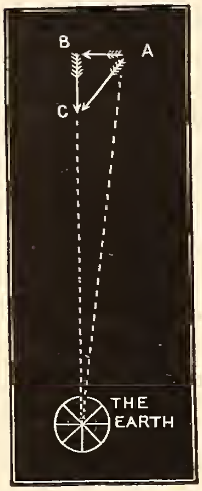
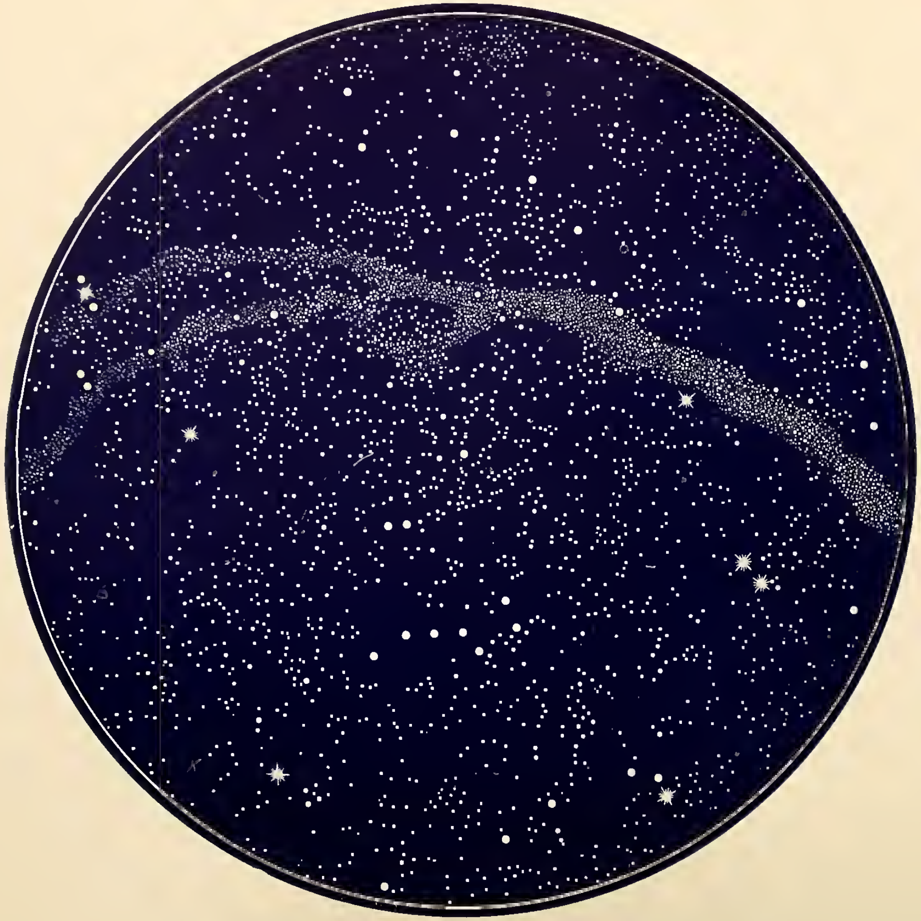


Fig. 11. Diagram showing how the actual velocity of stars is calculated.

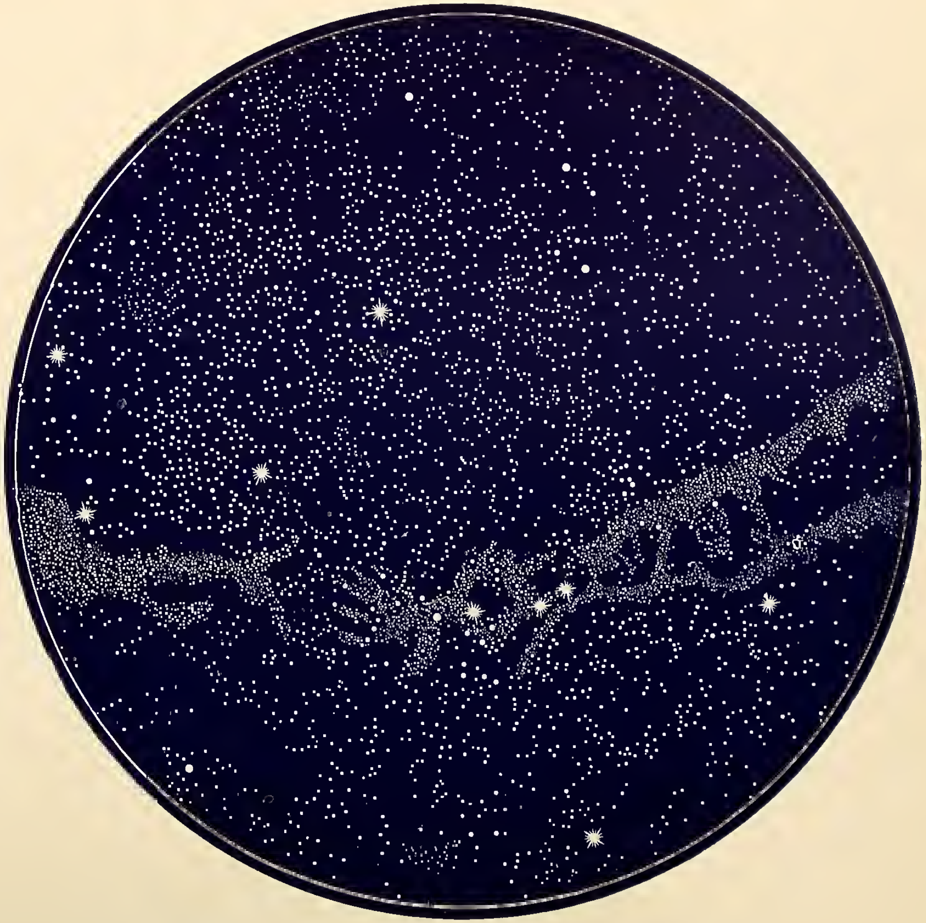
TABLE OF ACTUAL VELOCITY OF STARS.

α Centauri	has a probable minimum velocity of	27	miles per second.
Capella	,, ,, ,, ,, ...	30	,, ,,
Sirius	,, ,, ,, ,, ...	32	,, ,,
61 Cygni	,, ,, ,, ,, ...	40	,, ,,
Vega	,, ,, ,, ,, ...	50	,, ,,
ε Indi	,, ,, ,, ,, ...	65	,, ,,
Arcturus	,, ,, ,, ,, ...	70	,, ,,
No. 1830 of Groombridge Catalogue (a small star in Ursa Major),	has a probable minimum velocity of	200	,, ,,

THE STARS VISIBLE TO THE NAKED EYE—PLATE 4.



NORTHERN HEMISPHERE.



SOUTHERN HEMISPHERE.

CHAPTER III.

THE SIDEREAL HEAVENS.

"Roll on, ye stars! exult in youthful prime,
Mark with bright curves the printless steps of time;
Near and more near your beamy cars approach,
And lessening orbs on lessening orbs encroach."—*Erasmus Darwin.*

THE DISTANCES OF THE STARS.

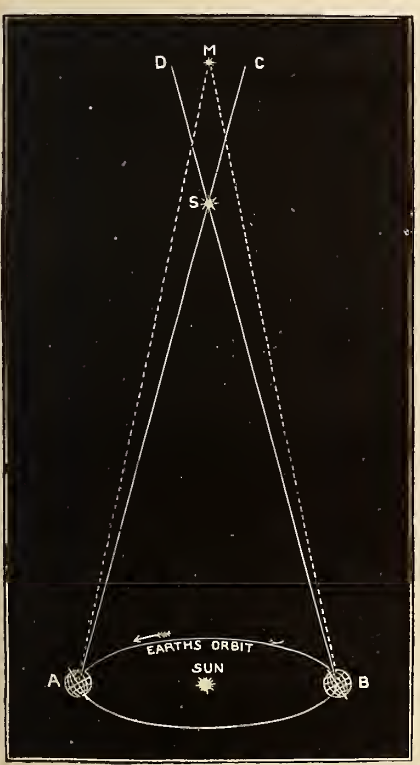


Fig. 12. Diagram showing how the distance of stars is measured.

That the stars are situated at great distances from our system is well known; but few, even for a moment, imagine how enormous those distances in reality are. Previous to the year 1838, astronomers even were uncertain as to the immensity of the spaces lying between us and many of the orbs composing the sidereal universe. In that year, the astronomer Bessel, from numerous delicate observations of the small star 61 of Cygnus, was enabled to announce that he had determined the distance of that orb; and had discovered something of the magnitude of the scale on which the great starry system was built. A short time afterwards, the distance of another star was determined. Henderson, from observations made in the Southern Hemisphere, found that the bright star α Centauri was situated from us at a distance of about half that of 61 Cygni, or about eighteen billions of miles. Since then the distances of quite a number of stars in both hemispheres have been very fairly determined; but in every case it has been found that these orbs are removed much further from us than α Centauri, which, therefore, still remains the nearest known star to our system.

The problem of determining the distances of the stars is one of the most difficult that the astronomer has to solve. It requires the highest observational skill that the human intellect is at present capable of, combined with the most accurate instruments that it is possible for human hands to make; and in the great majority of cases, the distances of those orbs are so enormous that it is impossible to discover them. In attempting the solution of this grand problem—viz., to apply the sounding line to the depths of space, the astronomer employs the same method as a surveyor when measuring the distance of some inaccessible object. A base line at right angles to the object is carefully measured, and from each end of it the angle between the object and the opposite end of the base line is determined, from which data, by means of the properties of triangles, the distance of the object can be calculated. In determining the moon's distance, a chord of the terrestrial surface can successfully be employed as a base line. The distance of the sun, however, is so great that even the whole diameter of our globe, or 7918 miles, is a base line too insignificant to measure it; while the stars are so far away that a base line even a hundred times longer would still be perfectly useless. Fortunately for astronomical science, a longer base line than this can be had, for in attempting the measurement of a star's distance, the astronomer employs one whose length is twenty-three thousand times greater than the diameter of the earth, for he employs the whole diameter of the *orbit* of our globe, a length of over 185 millions of miles. From one end of this enormous base line, the observer from the earth at A (*Figure* 12), carefully measures the angular distance of the star S, from some small and more distant star, as M, or he determines the very minute angle C A M Six months afterwards, when our globe has completed one-half of her annual revolution, and has carried the observer to the other end of his base line, at B, the star S will no longer appear at C, as when viewed from A, but at D, from the parallactic displacement of the star, brought about by the change of the observer's position. The astronomer, therefore, from his new position at B, determines the new angle M B D, and from these angles he can get the angle A S B, or the annual parallax of S, from which he can calculate the distance of the star.

It will be noticed from Fig. 12 that the further S is from A and B, or the more distant a star is from the earth, the smaller becomes its apparent angular displacement or its annual parallax. In the case of the nearest star, this minute angle is less than one *second* of arc, or about the same angle as that under which one quarter of an inch would appear as viewed from a distance of a mile; for the *nearest* star is no less than 275 *thousand* times more distant than the sun! This distance is so great, that an object, travelling continuously at the velocity of an express train, would only journey over it in about sixty millions of years, Even light, which in each second travels over a space of 186 thousand miles—thus reaching us from the moon in about one second and a-quarter, and from the sun in seven and a-half minutes—actually requires four years to reach our earth from *α* CENTAURI. Such is the distance of the nearest star! The star next in point of distance, or the small star 61 of CYGNUS, is situated at a distance of over 469 thousand times greater than that of the sun, and thus its light in journeying to us requires seven years. From the brilliant star *Sirius* light occupies ten years in travelling; from *Aldebaran*, fourteen years; from *Vega*, twenty-two years; and from *Polaris*, no less than thirty-six years.

These, however, are stars that lie nearest to our system. The vast majority of those seen with the unaided eye are situated at distances considerably greater than these. So vast are their distances in most cases, that no parallactic displacement can be detected, even with the most accurate and powerful instruments, viewed from opposite ends of that great base line, the diameter of the earth's orbit. Such are the distances of the stars visible to the naked eye. The millions of faint stars rendered visible by the telescope are undoubtedly more distant still; so that, in many instances, their light has occupied hundreds and thousands of years in traversing that mighty abyss which lies between them and our earth.

We do not, therefore, see the heavenly bodies in the positions they occupy, or in the conditions in which they exist, at present, but at the time when their light-rays, which now enter our eyes, first set out on their journey to our system. When we look at the moon, for instance, we see her as she existed one second ago; the sun, seven and a-half minutes ago; *α* CENTAURI, four years ago; and the other stars, tens, hundreds, and in many cases, thousands of years from the present time. The astronomer, then, when analysing the light of a star, does not thereby determine its present condition, but its condition some time in the distant past—hundreds of years, it may be, before the instrument he employs was known to the human race. Such, then, are the distances of the stars, which reveal to us the immensity of the depths of those parts of space that lie nearest to our system, and those still greater depths which lie beyond—depths which to us will probably ever remain unfathomable.

THE DISTANCES OF THE NEARER STARS.

NAME OF STAR.	*ANNUAL PARALLAX.*	*Number of times more distant from the Earth than the Sun.*	*DISTANCE.*	*Years occupied by light in travelling from the star to the Earth.*
α CENTAURI	0·75 seconds of arc.	275,000	25½ BILLIONS of miles	4·3 years.
61 CYGNI	0·44 ,, ,,	469,000	43½ ,, ,,	7·4 ,,
Sirius	0·33 ,, ,,	625,000	58 ,, ,,	9·9 ,,
Procyon	0·27 ,, ,,	761,000	70½ ,, ,,	12·0 ,,
σ DRACONIS	0·25 ,, ,,	838,000	78 ,, ,,	13·2 ,,
Aldebaran	0·24 ,, ,,	874,000	81 ,, ,,	13·8 ,,
ε INDI	0·22 ,, ,,	937,000	87 ,, ,,	14·4 ,,
Altair	0·19 ,, ,,	1,086,000	103 ,, ,,	17·1 ,,
η CASSIOPEIÆ	0·16 ,, ,,	1,272,000	118 ,, ,,	20·1 ,,
Vega	0·15 ,, ,,	1,373,000	127 ,, ,,	21·7 ,,
Capella	0·11 ,, ,,	1,875,000	174 ,, ,,	29·6 ,,
Arcturus	0·094 ,, ,,	2,194,000	203 ,, ,,	34·7 ,,
Polaris	0·089 ,, ,,	2,318,000	215 ,, ,,	36 ,,
μ CASSIOPEIÆ	0·060 ,, ,,	3,438,000	319 ,, ,,	54 ,,
No. 1830 *Groombridge Catalogue*	0·045 ,, ,,	4,583,000	425 ,, ,,	72 ,,

THE NATURE OF THE STARS.

The distances at which the stars are situated reveal to us something of their nature. When our earth was considered to be the centre of the universe, and before the telescope had been directed to the heavens, the stars were thought to be comparatively near, and were in consequence believed to be simply small lights suspended in the sky. When, however, the Copernican theory was established, the stars were proved to be very distant orbs indeed. Viewed from each end of the earth's orbit no large displacement could be detected, which proved the immensity of their distances. In fact, one of the chief arguments against the belief in the orbital movement of our globe, was the acceptance of the immensity of the stellar distances, and the gigantic sizes of the stars as a direct consequence. The earth, however, is now known to revolve; in several instances the distances of the stars have been determined; and from those distances it is also known that the stars are orbs, thousands of times larger than our globe, and in most cases gigantic even as our sun. Being self-luminous they were indeed looked upon as globes in every respect identical with the great centre of the solar system. They were believed to be gigantic, fiery, gaseous masses, in which there were ever taking place, as on our sun, the most tremendous disturbances. This with certainty is now known to be the case. That truly marvellous instrument, the spectroscope, when applied to the study of the heavens, at once revealed the fact that each star is really a sun. Being so distant, it of course appears very insignificant; but, if viewed from the same comparative nearness as we view our sun, it would in many instances appear several times larger and hotter than the solar orb. Our sun is thus simply an enlarged view of every one of the millions of stars revealed by means of the telescope; and each star, on the other hand, is a diminished view of our own gigantic sun.

As mentioned in a former chapter, these suns are constantly moving through the depths of space at velocities hundreds of times greater than the speed of a projectile—resembling, in fact, so many gigantic balls fired from some mighty piece of ordnance. Being suns, they are, therefore, centres of planetary systems; so that each orb in its majestic sweep through the infinite void, carries along with it its system of revolving worlds. Like his companions, our sun is also rapidly travelling through space. At present, his orbital velocity is thought to be about fifteen miles per second, which is considerably less than many of his fellow suns. That part of the heavens towards which he is travelling is situated on the confines of the constellation of HERCULES, near the brilliant star *Vega*—a point on the star-sphere diametrically opposite the place towards which the brightest star in the heavens, the star *Sirius*, is apparently moving.

DIFFERENT ORDERS OF STARS.

The spectroscope, however, not only proves that the stars are suns, but that, like the various planets, they are arranged into classes. *Sirius*, for instance, is found to belong to a type of star totally different in appearance from our sun. As seen in Plate 19, its spectrum is quite different from the solar spectrum. The chief characteristic in the spectrum of Sirius is the existence of several exceedingly broad, dark bands. These, as is now known, are produced by a dense layer of hydrogen gas surrounding the star, or forming part of its fiery atmosphere. The density of the gas, as witnessed in the breadth of the dark lines in the spectrum, is entirely owing to the great attraction exerted on it by the globe of the star—an attraction much greater than that exerted by our sun on the same gas forming part of his atmosphere. Thus, Sirius is a globe much more massive, or heavy, than the solar orb. But the mass of Sirius is known in another way. In the year 1862, a faint companion star was accidentally discovered revolving round Sirius. From the period of its revolution, combined with its distance, the mass of the larger star was determined. The two globes, distant though they be, can, as it were, be placed in the astronomer's scales, and compared with our sun; for the attraction of any two orbs, and the velocities of their revolutions, entirely depend on their weights or masses. From the fact, then, that the companion to *Sirius* completes its revolution in so short a period as forty-nine years, while its distance from him is greater than that of the planet Neptune from our central orb, *Sirius* is known to be about twenty-six times, and the companion about nine times, heavier than the sun.

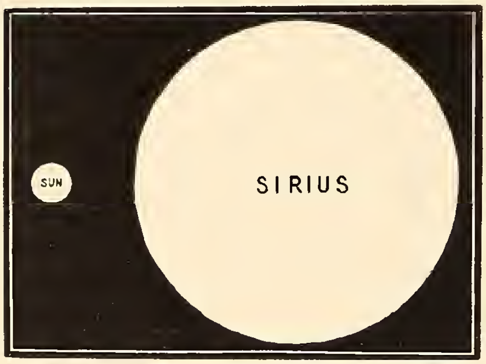


FIG. 13.

COMPARATIVE SIZES OF THE SUN AND SIRIUS.

But *Sirius* is not only very much heavier than our sun; he is also considerably larger. As already mentioned, he is the brightest star in the heavens, and being situated from us at a distance of over 625 thousand times that of the sun, it proves that in surface *Sirius* vastly exceeds our central orb. In fact, from his enormous distance and great brilliancy, *Sirius* is believed to exceed our sun in volume at least 500 times (*see Fig.* 13).

Sirius, then, belongs to a type of suns of a much higher order than our own. The stars of this class are, like Sirius, readily distinguished by their clear, bluish light. The class contains most of the brighter stars such as *Vega*, *Rigel*, *Procyon*, *Capella*, &c. The stars belonging to the second class, on the other hand, are of a yellowish colour, and have spectra much the same as the solar spectrum (*see Plate* 19). Now, as the hydrogen bands in the spectra of the stars of this type are not very conspicuous, and as the intensity of the light is not great, these suns are doubtless inferior in volume and mass to the members of the first type. In fact, between the members of these classes, there will be at least as marked a difference in dimensions as there is between the sun and Sirius. Thus, our sun belongs to an inferior order of suns, of which *Altair, Arcturus, Aldebaran*, &c., are members.

But the spectroscope has revealed the existence of a third class of stars (*see Plate* 19). Strangely enough the spectrum of the stars of this type is similar in appearance to the spectrum of a sun-spot, from which one would suppose that the stars of this class (to which α Herculis belongs) will have their surfaces greatly covered with sun-spots. Now, the spots on the solar surface are subject to a variation in number throughout a fairly regular period. Once in about every eleven years, for instance, the number of spots on the sun's surface, or the amount of solar disturbance of which the spots are indices, reaches its maximum; and midway between the epochs of maxima, very few spots are formed. Those stars, then, that have spectra like sun-spots will also probably have at one time many more spots on their surfaces than at another time. In short, each of the stars of this class will, like our sun, but in a more marked degree, have their maximum and minimum number of spots. Thus, one would suppose, these stars will not always shine with the same degree of brilliancy, as an increase of spots would certainly somewhat diminish the quantity of light radiated from their surfaces. This, indeed, is found actually to be the case with the majority of the stars belonging to this, the third type. In fact, these stars are for the most part what are known as Variable Stars—*i.e.*, stars whose brilliancy is subject to more or less variation throughout both regular and irregular periods.

TABLE OF CLASSES OF STARS.

FIRST CLASS. Stars of a bluish-white colour.			
Sirius.	*Fomalhaut.*	β, γ, ε, η Canis Majoris.	α, β, γ, δ Persei.
Vega.	*Regulus.*	δ, ε, ζ Orionis.	α, γ, λ Ophiuchi.
Rigel.	*Castor.*	α, γ, ζ Pegasi.	α, β, γ Coronæ Bor.
Procyon.	*Thuban.*	β, γ, δ, ε, ζ, η Ursæ Majoris.	α Piscium.
Spica.		β, δ, ε Cassiopeiæ.	β, δ, ζ, η Leonis.
SECOND CLASS. Yellowish Stars like the Sun.			
Altair.	*Arcturus.*	α, ζ, η Cassiopeiæ.	β, γ, η, θ, ι, ξ, χ Draconis.
Capella.	α, β, γ, ε, ζ, τ Cygni.	α, δ Serpentis.	β, ζ, η, π Herculis.
Pollux.	α Ursæ Majoris.	β, δ, ε, η, ϱ Bootis.	γ, ε, μ Leonis.
Aldebaran.	α^1, α^2 Capricorni.	β, γ, ζ, η Cephei.	β, ε Virginis.
THIRD CLASS. Red and Orange Stars.			
Antares.	*Alphard.*	β, φ Pegasi.	5 and o^1 Orionis.
Betelgeux.	α Herculis.	δ, σ Virginis.	ϱ, σ Persei.
Mira.	μ Cephei.	π, υ Aurigæ.	119 Tauri.

The stars of this third class are generally of a reddish colour, thus, probably, denoting a further and cooler stage than the yellow stars—the class to which our sun belongs. These three orders of suns above-mentioned are the principal types into which the stars in our sidereal universe are divided, as at present known. A fourth class has recently been revealed, but the stars belonging to it are not very brilliant, and are evidently suns considerably smaller than our own. Very probably there are numerous other classes yet to be discovered Enough, however, has already been revealed to show clearly that the stars are not all built on one plan, as was once supposed, but that, as in the solar system, there are different orders of planets, so in the immensity of star-strewn space, there are various orders of suns; that among the stars, as everywhere in Nature, there is, along with a wonderful unity, the greatest variety—in size, condition, light, heat, colour, and movement; and that, indeed, "one star differeth from another star in glory."

DOUBLE STARS.

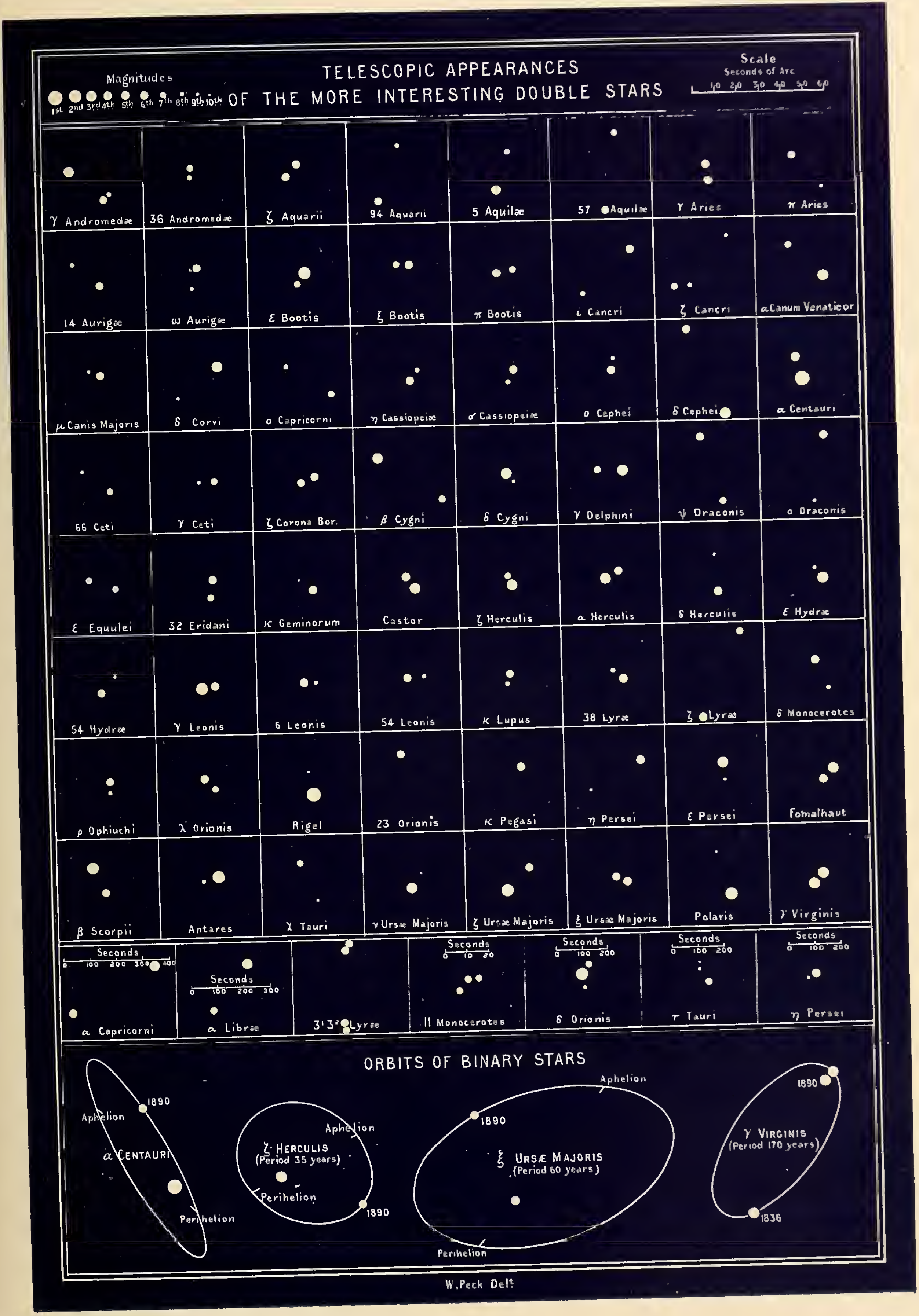
In the year 1664 the astronomer Hooke, while observing a comet, accidentally viewed the star γ in the constellation of ARIES, and was surprised to find that it was unlike many others he had seen, in respect of its being composed of two stars. In this manner was the first double star discovered. Since that time, with each improvement of the telescope, large numbers of others have been found, till at present no less than upwards of *ten thousand* are known, and this number is steadily being added to every year. In most cases the angular distances between the components do not exceed thirty seconds of arc, being often as close as one quarter of a second. The closer ones require, of course, the most powerful instruments to render them visible, because the greater number of telescopes do not separate double stars which are closer than one second. Recently, by means of the spectroscope, several double stars that are closer than even the most powerful telescope will divide, have been discovered; as from its revolution the changing position of the small star produces a regular widening of the dark lines of the spectrum. In Plate 5 there are given telescopic views of the more remarkable of these objects, and the positions of many hundreds of them are indicated in the accompanying twelve large Charts of the Heavens.

The double stars are in general beautifully coloured. In the case of those whose components are nearly equal in magnitude there is no contrast of colour whatever. In the case of those, however, where the companion greatly differs from the larger one in size, the colours distinctly differ, and perfectly blend. The colours of the components are, in fact, what is known as complementary, for the colour of the small star lies further up, or nearer the violet end of the spectrum, than the colour of the large one. If the larger star, for example, is of an orange colour, the smaller one is then of a bluish tint; and if red in colour, the companion is green. Seeing that this peculiarity exists, one might suppose that the components of a double star would in some way be connected. Such, indeed, in many instances, is really the case; for the two suns are found to have movements which are produced by each other's attraction. In Plate 5 there are represented the orbits of four of the more remarkable of these *binary* stars, as they have been designated—viz., of α CENTAURI, of ζ HERCULIS, of γ VIRGINIS, and of ξ URSÆ MAJORIS. The periods in which the companions complete their orbital revolutions depend, of course, on the weights, or masses, of the larger stars, and the distances between the components, and are thus likely to have a considerable range. The shortest known period of revolution of a binary star, as in the case of δ EQUULEI, is one of fourteen years; while the longest, as in ζ AQUARII, is about 1600 years.

But not only are two stars physically connected; three and often more stars sometimes form one system. One of the most remarkable of the multiple systems is ϵ LYRÆ, a small star near the bright star *Vega*. With a very small telescope this object appears as a well separated double star. In larger instruments, however, each of the components is again divided into two stars, so that it is in reality a double binary system (*see Plate* 5). Another remarkable system is the triple one of ζ CANCRI; the members of which perform rather curious movements. The two large stars revolve round their common centre of gravity after the ordinary manner of binary stars, in a period of about sixty years; while the third, and smallest star, moves slowly round the two large orbs in a much longer period—one probably of several hundred years in extent.

In other instances the components of multiple systems are not arranged into pairs, but are situated from each other, as in the case of the star θ ORIONIS, at nearly equal distances. This, from the constantly altering attractive forces of the different members of the group on one another, will produce more wonderful movements even than those above-mentioned. These cases, however, are not very numerous. In general a large star is seen with several tiny companions, an arrangement more of the nature of a large sun and smaller ones, or planets, revolving round it. These apparently tiny companions, requiring the largest telescopes to render them visible, are not by any means insignificant. If, for instance, a planet as gigantic as JUPITER revolved round the nearest star, it would be invisible to the most powerful instrument. This proves that the small

DOUBLE STARS—PLATE 5.


TELESCOPIC APPEARANCES
OF THE MORE INTERESTING DOUBLE STARS
Magnitudes
1st 2nd 3rd 4th 5th 6th 7th 8th 9th 10th
Scale
Seconds of Arc
10 20 30 40 50 60
γ Andromedæ
36 Andromedæ
ζ Aquarii
94 Aquarii
5 Aquilæ
57 Aquilæ
γ Aries
π Aries
14 Aurigæ
ω Aurigæ
ε Bootis
ξ Bootis
π Bootis
ι Cancri
ζ Cancri
α Canum Venaticor
μ Canis Majoris
δ Corvi
ο Capricorni
η Cassiopeiæ
σ Cassiopeiæ
ο Cephei
δ Cephei
α Centauri
66 Ceti
γ Ceti
ζ Corona Bor.
β Cygni
δ Cygni
γ Delphini
ψ Draconis
ο Draconis
ε Equulei
32 Eridani
κ Geminorum
Castor
ζ Herculis
α Herculis
δ Herculis
ε Hydræ
54 Hydræ
γ Leonis
6 Leonis
54 Leonis
κ Lupus
38 Lyræ
ζ Lyræ
δ Monocerotes
ρ Ophiuchi
λ Orionis
Rigel
23 Orionis
κ Pegasi
η Persei
ε Persei
Fomalhaut
β Scorpii
Antares
χ Tauri
ν Ursæ Majoris
ζ Ursæ Majoris
ξ Ursæ Majoris
Polaris
γ Virginis
Seconds
0 100 200 300 400
α Capricorni
Seconds
0 100 200 300
α Libræ
3¹ 3² Lyræ
Seconds
0 10 20
11 Monocerotes
Seconds
0 100 200
δ Orionis
Seconds
0 100 200
τ Tauri
Seconds
0 100 200
η Persei
ORBITS OF BINARY STARS
Aphelion
1890
α Centauri
Perihelion
ζ Herculis
(Period 35 years)
Aphelion
Perihelion
1890
Aphelion
1890
ξ Ursæ Majoris
(Period 60 years)
Perihelion
1890
γ Virginis
(Period 170 years)
1836
W.Peck Delt

companions seen surrounding those stars, which, like *Vega*, are known to be many times more distant than *α* CENTAURI, are undoubtedly hundreds of times larger than the giant planet of our system. In fact, as already mentioned, one of these faint companions, the satellite of *Sirius*, is even more massive and gigantic than our sun.

TABLE OF BINARY STARS.

NAME OF STAR.	*MAGNITUDES OF COMPONENTS.*	*PERIOD OF REVOLUTION.*	*NAME OF STAR.*	*MAGNITUDES OF COMPONENTS.*	*PERIOD OF REVOLUTION.*
δ EQUULEI . .	4·5 and 5	14 years	ξ BOÖTIS . .	4·5 and 6·5	127·4 years
42 COMAE BER. .	6 ,, 6	25·7 ,,	4 AQUARII . .	6 ,, 7	129·8 ,,
8 SEXTANTIS .	5·5 ,, 6·5	33 ,,	γ VIRGINIS . .	3 ,, 3·2	185 ,,
ζ HERCULIS .	3 ,, 5·5	34·4 ,,	o^2 ERIDANI . .	9·5 ,, 10·5	200 ,,
η CORONAE BOR. .	5·5 ,, 6	41·6 ,,	τ OPHIUCHI .	5 ,, 6	218 ,,
Sirius . .	1 ,, 9	49 ,,	η CASSIOPEIÆ .	4 ,, 7·3	195·2 ,,
γ CORONAE AUST.	5·5 ,, 5·5	55 ,,	44 BOOTIS . .	5·3 ,, 6	261 ,,
ζ CANCERI (triple)	A. 5·5 B. 6·2 C. 6·6	60 ,,	μ^2 BOOTIS . .	6·5 ,, 8	280 ,,
		600 ,,	δ CYGNI . .	3 ,, 8	336 ,,
ξ URSÆ MAJORIS	4 and 5	60·8 ,,	36 ANDROMEDAE .	6 ,, 7	349 ,,
α CENTAURI .	1 ,, 2	77·4 ,,	γ LEONIS . .	2 ,, 3·5	407 ,,
70 OPHIUCHI .	4·5 ,, 6	94·4 ,,	μ DRACONIS .	5 ,, 5	562 ,,
γ CORONAE BOR. .	4 ,, 6	95·5 ,,	12 LYNCIS . .	6 ,, 6·5	676 ,,
ξ SCORPII . .	5 ,, 5·2	96 ,,	σ CORONAE BOR. .	5.5 ,, 6·5	846 ,,
ω LEONIS . .	6 ,, 7	111 ,,	*Castor* . .	2·5 ,, 2·8	997 ,,
25 CANUM VENAT.	6 ,, 7	124 ,,	ζ AQUARII . .	4 ,, 5·5	1600 ,,

VARIABLE STARS.

When the stars are closely examined from time to time, it is found that a number of them alter in brilliancy. In fact, every star in the heavens must slowly or otherwise be changing in brightness; for it cannot be supposed that a fiery gaseous mass, such as a star, can long remain in the same condition as to temperature, and consequently as to the amount and intensity of its light. Within historic times there are several instances where stars have either diminished in brightness, or their surrounding companions have increased. If during only the last few hundred years accurate determination of the relative brilliancy of the stars had been made, as is done now, the known number of cases of gradual variation would doubtless be very great indeed; as all the stars are growing older, and must ultimately become dark orbs. These stars, however, whose light is thus subject to a gradual diminution, are not what are properly known as variable stars. Variable stars are those whose lustre passes from a maximum to a minimum in periods that are either regular or irregular.

Like the ordinary stars, those that are variable can be arranged into classes. The brilliancy of those that belong to the first class fluctuates in a very regular period. This class is what is known as the "Algol type," from the star *Algol*, in the constellation of PERSEUS, the first star of this class discovered.

Algol, in general, shines as a second magnitude star; once every sixty-nine hours, however, it slowly decreases in brightness, till in about four and a-half hours it has lost about five-sixths of its light, and appears as a star of the fourth magnitude. It now shines as such for about nineteen minutes, and then in three and a-half hours' time regains its maximum brightness, and retains it for the remaining part of its short period. These regular variations to which the light of the stars of the "Algol type" are subject can only be produced by large, dark planets revolving round them, as the spectrum remains unaltered throughout the entire period of revolution, being only diminished in brightness. Each time, for instance, the dark companion to one of these stars passes exactly between us and the star, a partial eclipse takes place; a considerable quantity of light is thus intercepted; and the star shines with greatly diminished brightness. In fact, from the known distance of the star, and the amount and variation of its light, it is possible to determine the approximate size of the star and its companion. In the case of *Algol* it is thought that the star itself is a sun whose diameter is about one million of miles; while the companion is a globe about the same size as our sun.

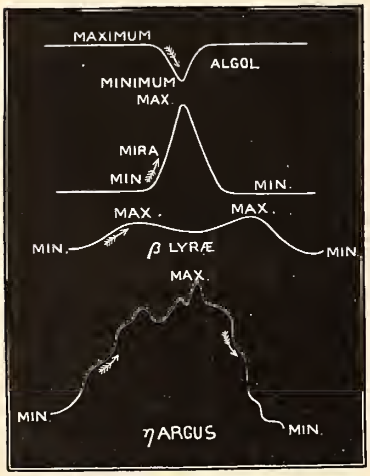


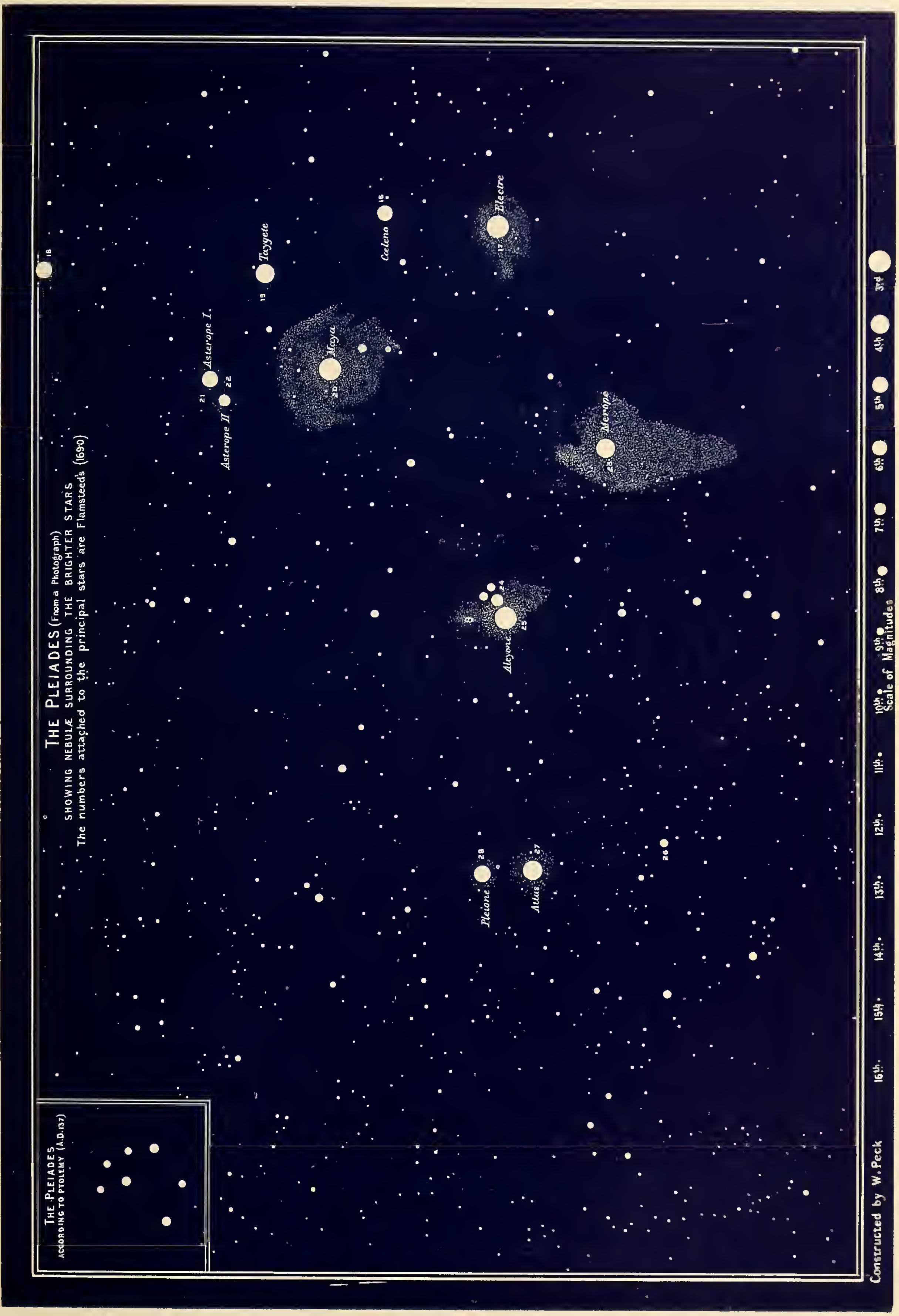
Fig. 14. CURVES SHOWING VARIATION OF MAGNITUDE OF DIFFERENT CLASSES OF STARS.

The variations of lustre of the next class of stars are performed in exactly the opposite manner to those of the Algol type. Instead of shining for the most part at the maximum brilliancy, and decreasing in magnitude only for short intervals, the stars of this class shine generally at the *minimum* lustre, and increase their light at fairly regular intervals. The first star belonging to this type was discovered in the year 1596. It is a star situated in the constellation of Cetus, called *Mira*—the wonderful. Usually this remarkable star is invisible to the unaided eye, and appears as faint as a star of the tenth magnitude. It becomes visible, however, once every eleven months, and increases in brightness until it sometimes appears as conspicuous as a second magnitude star. This maximum brilliancy is retained for but little over a week, when, more slowly than at its increase, the star again gradually becomes invisible. These variations from minimum to maximum, and then back to minimum again, occupy about three months; so that for about eight months at a time the star cannot be seen without the aid of a telescope.

The third type of stars is well represented by the star β Lyrae. In this case the variations take place somewhat regularly, but in each period two, and sometimes more, maxima and minima occur.

The stars of the fourth group perform their variations in a manner that is totally different from any of the above-mentioned types. Like the members of these classes, the stars of the fourth type often have a great range of variation; but, unlike those stars, the variations of the last-mentioned group are performed in irregular periods. The principal star of this class is situated in the southern hemisphere in the constellation of Argo, the star η, certainly the most remarkable variable star in the heavens. In this star the range of magnitude is probably more extensive than in any other. Sometimes it is so conspicuous that it rivals even Sirius, the brightest of all stars, while at other times it is invisible to the naked eye; thus radiating at maximum, no less than twenty-five thousand times more light than at minimum. These variations of lustre do not, as indicated by Figure 14, occur regularly, and the increase or decrease of brilliancy is not uniform, or continuous. Strangely enough this remarkable star is surrounded by a nebula, which in some way appears to be connected with the star; as its misty light is also subject to variation.

There is yet another class of stars which may be mentioned—a class that at first sight does not seem to be in any way connected with the variable stars. This type, however, may simply be a different stage of the *Mira* class—*i.e.*, stars which do not in general appear conspicuous, and only occasionally increase their light.



THE PLEIADES (From a Photograph)
SHOWING NEBULÆ SURROUNDING THE BRIGHTER STARS
The numbers attached to the principal stars are Flamsteeds (1690)

18
19 Taygete
16 Celeno
17 Electre
21 Asterope I.
22 Asterope II.
20 Maya
23 Merope
24
25 Alcyone
28 Pleione
27 Atlas
26
THE PLEIADES ACCORDING TO PTOLEMY (A.D. 137)
Scale of Magnitudes
3rd
4th
5th
6th
7th
8th
9th
10th
11th
12th
13th
14th
15th
16th

Constructed by W. Peck

TABLE OF THE MORE INTERESTING VARIABLE STARS.

FIRST CLASS.

NAME OF STAR.	RANGE OF VARIATION OF MAGNITUDE.	PERIOD.
β PERSEI (*Algol*),	2·3 to 3·5	2 d. 20 h. 49 m. 55 s.
λ TAURI,	3·4 „ 4·2	3 d. 22 h. 52 m. 12 s.
S MONOCEROTIS,	4·9 „ 5·4	3 d. 9 h. 36 m.
R CANIS MAJORIS,	5·9 „ 6·7	1 d. 3 h. 15 m. 55 s.
δ LIBRAE,	5 „ 6·2	2 d. 7 h. 51 m. 23 s.
U OPHIUCHI,	6 „ 6·7	0 d. 20 h. 7 m. 42 s.
Y SAGITTARII,	6·2 „ 7·4	2 d. 10 h. 5 m.
U CEPHEI,	7 „ 9	2 d. 11 h. 50 m.

SECOND CLASS.

NAME OF STAR.	RANGE OF VARIATION OF MAGNITUDE.	PERIOD.
o CETI (*Mira*),	1·7 to 9·5	331·3 days.
T MONOCEROTIS,	6 „ 7·6	27 days.
R LEONIS,	5 „ 10	313 days.
R HYDRAE,	3·5 „ 10	497 days.
R CORONAE,	6 „ 12	376 days.
χ^2 CYGNI,	4·5 „ 13	406 days.
R AQUARII,	5·8 „ 11	287 days.
R ANDROMEDAE,	5·6 „ 13	411 days.

THIRD CLASS.

NAME OF STAR.	RANGE OF VARIATION OF MAGNITUDE.	PERIOD.
ζ GEMINORUM,	3·7 to 4·5	10 d. 3 h. 41 m. 30 s.
68 (u) HERCULIS,	4·5 „ 5·6	38 d. 12 h.
β LYRAE,	3·4 „ 4·5	12 d. 21 h. 46 m. 56 s.
ε AQUILAE,	3·5 „ 4·7	7 d. 4 h. 14 m.
T VULPECULAE,	5·5 „ 6·5	4 d. 10 h. 29 m.
δ CEPHEI,	3·7 „ 4·9	5 d. 8 h. 47 m. 40 s.
R AURIGAE,	6 „ 12	464 days.

FOURTH CLASS.

NAME OF STAR.	RANGE OF VARIATION OF MAGNITUDE.	PERIOD.
η ARGÛS,	1 to 7	About 70 years.
T CETI,	5 „ 7	About 65 days.
ε AURIGAE,	3 „ 4·5	Very irregular.
R CORONAE,	6 „ 13	Very irregular.
α HERCULIS,	3·1 „ 3·9	From 26 to 60 days.
T SCORPII,	7 „ 10	Irregular.
β PEGASI,	2·2 „ 2·7	Very irregular.

FIFTH CLASS (TEMPORARY STARS).

DATE OF APPEARANCE.	IN THE CONSTELLATION OF	MAGNITUDE.
July, 134 B.C.	SCORPIO, near β,	1st.
December, 123 B.C.	OPHIUCHUS, near α,	1st.
10th December, 173 A.D.	CENTAURUS, near α,	1st.
329 A.D.	AQUILA,	
March, 369 A.D.	Unknown,	
April, 386 A.D.	SAGITTARIUS, near λ,	Very bright.
„ 389 A.D.	AQUILA, near α,	1st.
„ 393 A.D.	SCORPIO,	Very bright.
„ 827 A.D.	SCORPIO,	1st.
„ 945 A.D.	Between CASSIOPEIA and CEPHEUS,	Very brilliant.
May, 1012 A.D. (or 1011, or 1006).	ARIES,	Exceedingly brilliant.
July, 1202 A.D.	In the tail of SCORPIO,	1st.
December, 1230 A.D.	OPHIUCHUS, near SERPENS,	1st.
July, 1264 A.D.	CASSIOPEIA, near CEPHEUS,	Very bright.
11th November, 1572 A.D.	CASSIOPEIA, near ϰ (*Tycho's Star*),	1st.
February, 1578 A.D.	Unknown,	Very bright.
1st July, 1584 A.D.	SCORPIO, near π,	Very brilliant.
18th August, 1600 A.D.	CYGNUS, near γ,	3rd.
10th October, 1604 A.D.	OPHIUCHUS, near θ (*Kepler's Star*),	1st.
1609 A.D.	Unknown,	Very bright.
20th June, 1670 A.D.	VULPECULA, near β CYGNI,	3rd.
28th September, 1690 A.D.	SAGITTARIUS, near π,	4th.
28th April, 1848 A.D.	OPHIUCHUS, near η (*Hind's Star*),	5th.
1860 A.D.	T SCORPIO in M. 80,	7th.
12th May, 1866 A.D.	CORONA BOREALIS, near ε,	2nd.
24th November, 1876 A.D.	CYGNUS, near ϱ,	3rd.
September, 1885 A.D.	ANDROMEDA, in the centre of the Great Nebula,	6th.

Such are the so-called "temporary" or "new" stars. These stars from time to time appear suddenly in different parts of the heavens, at first being exceedingly conspicuous, and then gradually fading in lustre till once more they become invisible. Within historic times there are no less than twenty-seven recorded instances of such stars having been seen. The first was observed in the year 134 B.C., and was the means of suggesting to Hipparchus the necessity of forming a catalogue of the positions of the more important stars. The most conspicuous one of the class, however, did not appear till the eleventh of November, 1572. This star is well known as Tycho's star, as that astronomer made many observations of it. It appeared in the constellation of CASSIOPEIA, near the small star κ, and in a few days' time reached its maximum brilliancy. This was equal to the brightness of Venus, and thus the star could be distinctly seen in daylight. It did not long remain at this brilliancy, but faded gradually away, till, sixteen months after its appearance, in February, 1574, it became invisible. This remarkable object it is believed appeared 308 years previously, or in the year 1264, and also in the year 945, or 629 years previously. Thus the star is probably but the member of another type of variable stars, whose extensive fluctuations occur in very long and irregular periods. In this particular instance, the period of maximum brightness lies doubtless somewhere between 308 and 319 years: so that it is not altogether improbable that within the next few years there may be witnessed another sudden appearance of the same star.

During the month of May, 1866, another temporary star suddenly appeared. It shone out in the constellation of the NORTHERN CROWN, as a star of the second magnitude. The period of visibility in this instance was not so long as in the one mentioned above, as this star only retained its greatest brightness for about four weeks, and in so short a time as five weeks it disappeared and reached its present brilliancy, the ninth magnitude. Fortunately, on this occasion the "new" star could be very minutely observed—far more accurately than the star of Tycho. The spectroscope, that powerful instrument of modern analysis, could now be advantageously employed (*see Plate* 19). That wonderful instrument, when applied to the blazing star, showed that it was surrounded with a large quantity of luminous gas—gas whose temperature was probably suddenly raised by the downfall of some mighty mass of matter.

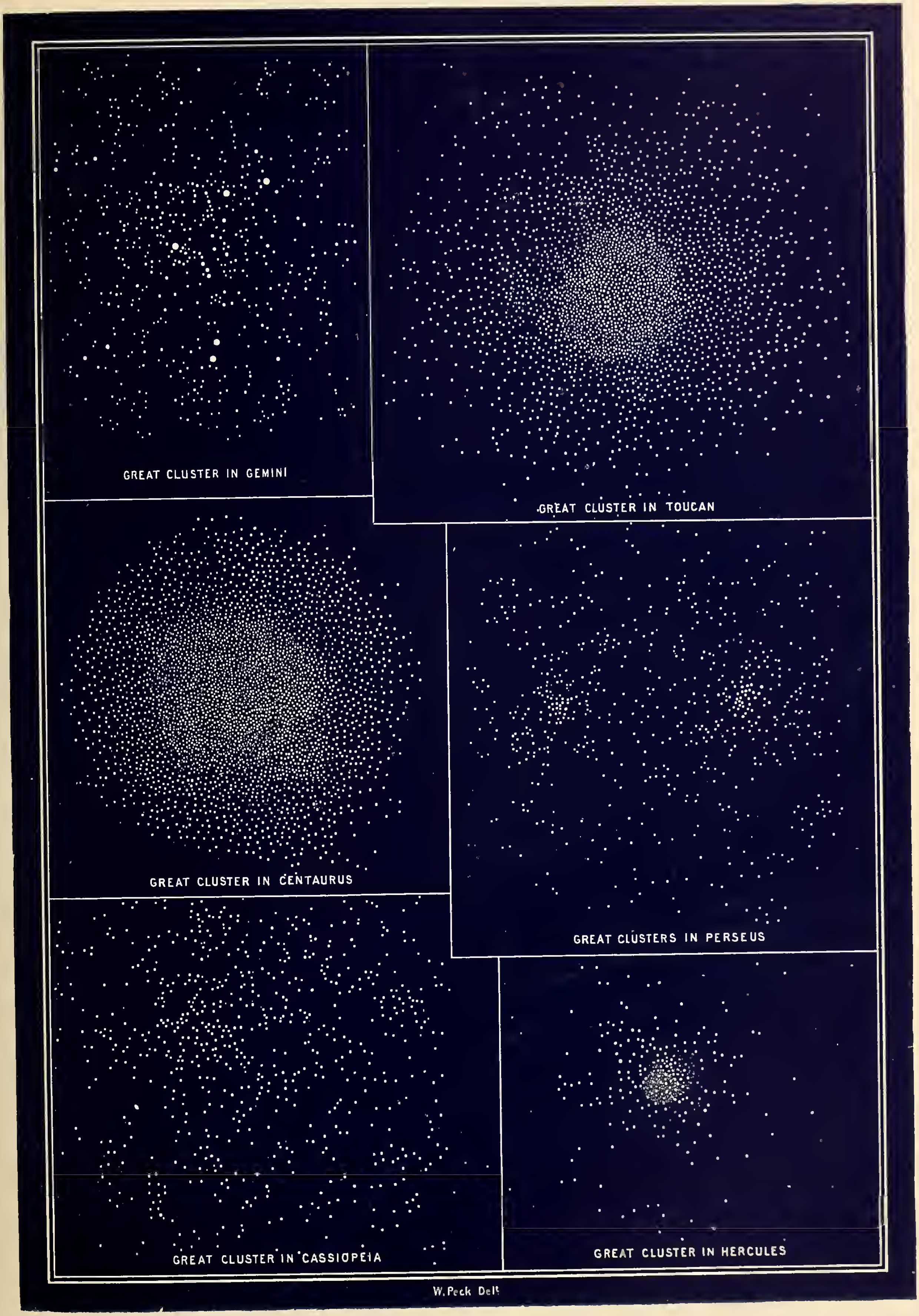
The variations of many of the so-called new stars are thus not improbably produced by swarms of meteors revolving round them in paths whose perihelia lie very near the stars. Every time, for instance, that the cluster passes closely to the star, a considerable quantity of the meteoric matter will, by the star's attraction and the retarding influence of its extensive atmosphere, be dragged to its surface. This will be sufficient to suddenly raise the temperature of the star, and thereby increase its brightness to such an extent as to make it appear a conspicuous object in the heavens.

Other variable stars, again, especially those of the third and fourth types, may have their fluctuations produced by a gradual increase and decrease of the number of spots on their surfaces. And so these stars may be somewhat like our sun in the variation of his spots, only in a more marked degree; a supposition that seems to be remarkably borne out by the spectra of their light, and, within certain limits, the irregularity of their periods.

STAR CLUSTERS AND NEBULÆ.

In various parts of the heavens stars are seen crowded together, forming what are called star clusters. Several of these objects can be distinctly seen with the unaided eye, but the greater number require the telescope to render them visible. The most conspicuous of the naked-eye groups, the well-known *Pleiades*, is situated in the constellation of TAURUS. Plate 6 is a view of this group as taken from a recent telescopic photograph. In this cluster, with ordinary eyesight only, six or seven stars can be seen, but with the telescope the number increases with the space-penetrating power, and with some instruments over 400 stars can be counted. The *Praesepe*, or Bee-Hive, in CANCER is another very conspicuous group, and one well seen by the

STAR CLUSTERS—PLATE 7.



GREAT CLUSTER IN GEMINI

GREAT CLUSTER IN TOUCAN

GREAT CLUSTER IN CENTAURUS

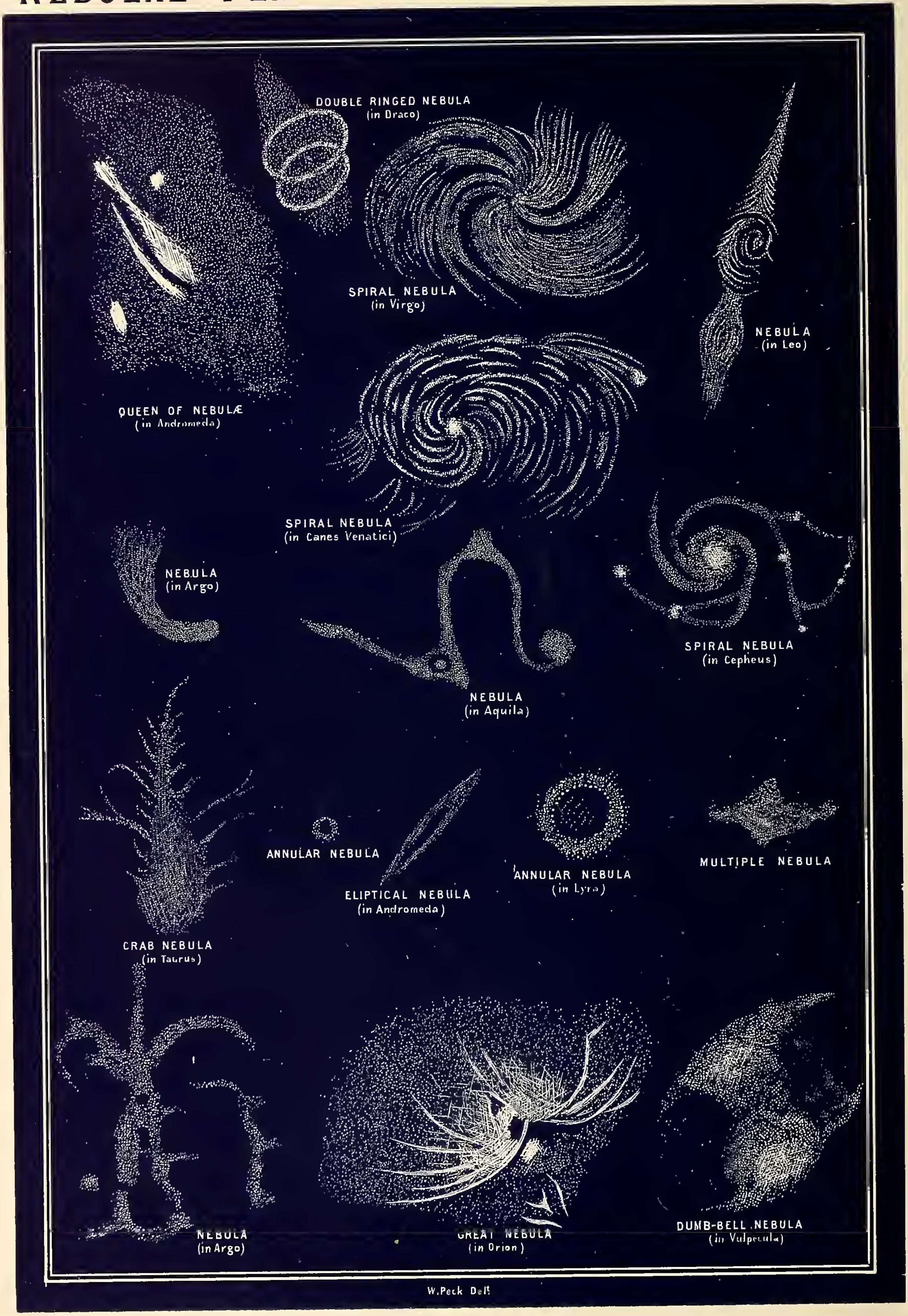
GREAT CLUSTERS IN PERSEUS

GREAT CLUSTER IN CASSIOPEIA

GREAT CLUSTER IN HERCULES

W. Peck Delt.

NEBULAE—PLATE 8.


DOUBLE RINGED NEBULA
(in Draco)
QUEEN OF NEBULÆ
(in Andromeda)
SPIRAL NEBULA
(in Virgo)
NEBULA
(in Leo)
SPIRAL NEBULA
(in Canes Venatici)
NEBULA
(in Argo)
SPIRAL NEBULA
(in Cepheus)
NEBULA
(in Aquila)
ANNULAR NEBULA
ELIPTICAL NEBULA
(in Andromeda)
ANNULAR NEBULA
(in Lyra)
MULTIPLE NEBULA
CRAB NEBULA
(in Taurus)
NEBULA
(in Argo)
GREAT NEBULA
(in Orion)
DUMB-BELL NEBULA
(in Vulpecula)
W.Peck Delt

aid of a small telescope; and also the clusters in PERSEUS and GEMINI. In the constellation of HERCULES there is situated one of the finest clusters in the heavens (*see Plate* 7). This extremely beautiful object, of a globular form, is estimated to contain no less than fourteen thousand suns. Many of the star clusters are so distant, that even with the most powerful instruments they appear simply as faint hazy masses. Whenever this is the case, and they cannot be resolved into glittering points, or individual stars, they are called NEBULÆ. No less than about seven thousand of these wonderful objects have been discovered.

Like the stars, these objects are arranged into different classes. First, there are nebulæ whose forms are exceedingly indefinite, and whose boundaries increase with the power of the telescope employed. The largest of this class is well represented by the "Great Nebula" in the sword-handle of ORION, and the "Queen of Nebulæ" in the constellation of ANDROMEDA. Several of the nebulæ of this class are, like the nebulæ in the *Pleiades* (Plate 7), so faint that they cannot be seen even with the largest telescopes, and are only rendered visible by means of the sensitive photographic plate. Next, there are nebulæ, with fairly regular forms, like the Dumb-bell nebula in VULPECULA (*see Plate* 8*a*), and the Crab nebula in TAURUS (*see Plate* 8). Thirdly, several appear to be arranged in a spiral shape, a class which is exceedingly faint, and whose discovery in the year 1846 was entirely owing to the labours of Lord Rosse (*see Plate* 8*b*). Fourthly, there are what are called annular nebulæ—objects like the remarkable one in the constellation of LYRA, that appear in the form of luminous rings. And, lastly, there is, perhaps, the faintest class of all, the planetary nebulæ—objects which appear like large indistinct planets, with either round or elliptical discs.

TABLE OF NUMBER OF STARS OF EACH MAGNITUDE.

VISIBLE TO THE NAKED EYE.	ONLY SEEN BY AID OF THE TELESCOPE.		
20 stars of the 1st magnitude	13,000 stars of the 7th magnitude	30 million stars of the 14th magnitude	
59 ,, ,, 2nd ,,	40,000 ,, ,, 8th ,,	90 ,, ,, 15th ,,	
182 ,, ,, 3rd ,,	100,000 ,, ,, 9th ,,	270 ,, ,, 16th ,,	*According to Calculation.*
530 ,, ,, 4th ,,	400,000 ,, ,, 10th ,,	820 ,, ,, 17th ,,	
1600 ,, ,, 5th ,,	1,000,000 ,, ,, 11th ,,	2500 ,, ,, 18th ,,	
4800 ,, ,, 6th ,,	3,000,000 ,, ,, 12th ,,	7000 ,, ,, 19th ,,	
	10,000,000 ,, ,, 13th ,,	22,000 ,, ,, 20th ,,	

These nebulæ, as above indicated, were at one time supposed to be simply huge clusters of suns, removed to distances so enormous as to give them the appearance of faint cloudy masses. As soon as the spectroscope, however, was employed in this portion of sidereal research, it proved beyond a doubt that in many cases the nebulæ were gigantic masses of luminous gas. These objects, therefore, cannot be huge stellar systems far outside our own, but simply comparatively tiny portions, of one great aggregation of a wonderful variety of orbs, composing the sidereal universe to which our own sun belongs. This is remarkably confirmed by the very arrangement of the nebulæ. Like the stars they are not indefinitely scattered over the heavens, but distributed somewhat according to law. In the case of the stars this would at first sight seem not to be the fact, as a cursory view of the heavens does not reveal the nature of star arrangement. It requires, in fact, careful telescopic examinations of the numbers of stars in all parts of the star-sphere, before the manner of distribution can be recognised.

With the unaided eye, as is well known, about six thousand stars only can be seen in both hemispheres, as represented in Plate 4. This, however, is but a very insignificant portion of the actual number as revealed with the telescope. To the naked eye, stars much fainter than the 6th magnitude cannot be seen, but with the largest instruments, stars as faint as the 16th and 17th magnitude are rendered visible, as indicated in the following Table:—

STARS VISIBLE WITH TELESCOPES OF DIFFERENT SIZES.

Diameter of object glass, or speculum, of telescope in inches,	½	¾	1	1½	2½	4	6½	10	16	25	40
Smallest Magnitude of star revealed, . . .	7th	8th	9th	10th	11th	12th	13th	14th	15th	16th	17th

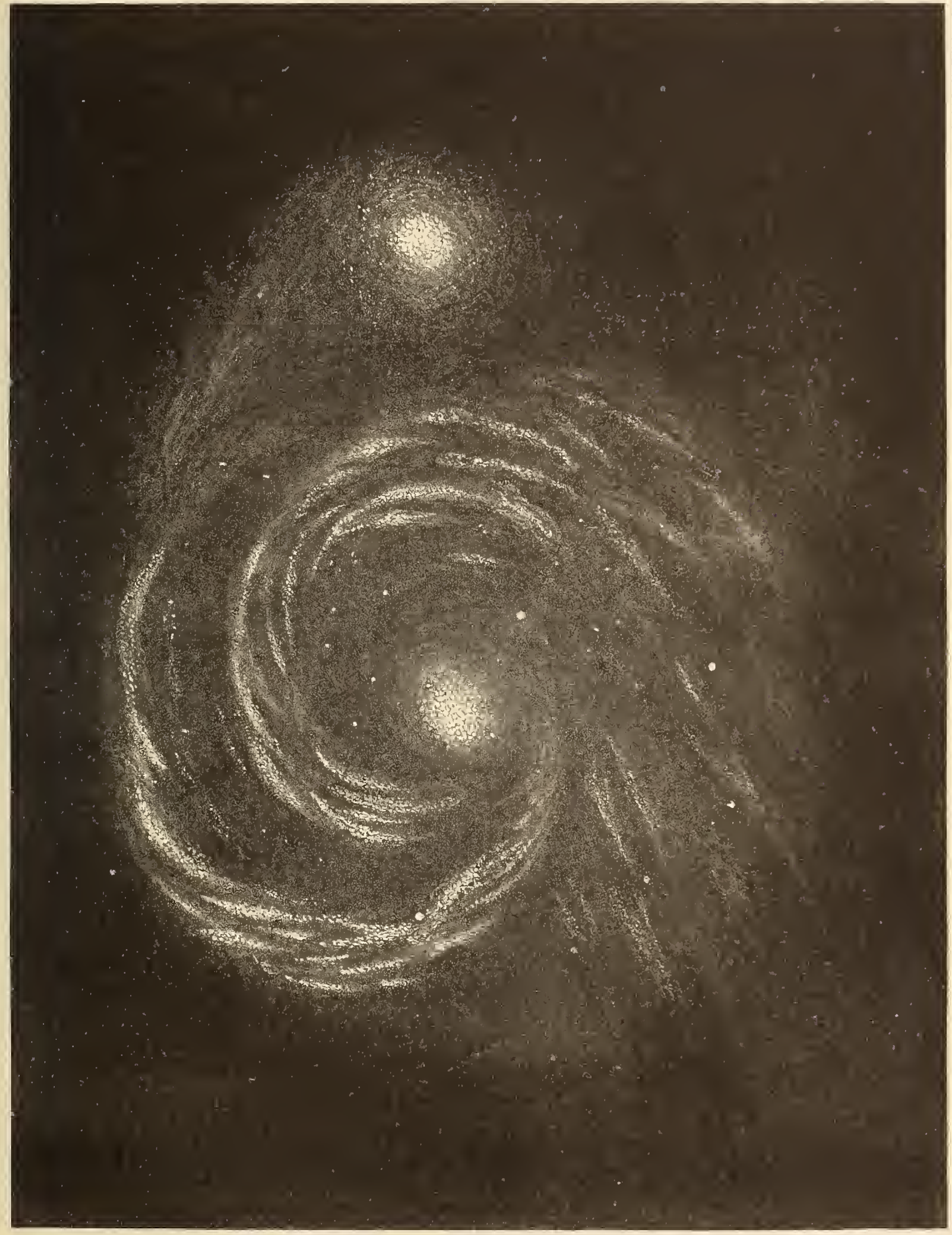
As would naturally be expected, the number increases as the stars diminish in brightness; consequently, while scarcely six thousand stars can be seen with the naked eye, no less than about one hundred millions are rendered visible with the largest instruments. The number of stars in each magnitude is given in the Table on page 29. Thus it is highly probable that down to the twentieth magnitude—a magnitude at present invisible even to the most powerful telescope—there are upwards of thirty thousand millions of stars. As already mentioned, these millions of orbs are not equally distributed in the heavens, but are greatly more condensed in some places than in others. In fact, it is found that they increase in number when that luminous great circle of the star sphere, the Milky Way, is approached. The nebulæ, on the other hand, *decrease* in as great a proportion towards the Milky Way, and are densely clustered in two places on the star sphere which are situated perpendicularly to that cloudy zone, or in parts of the heavens surrounding its poles. There are, therefore, in the heavens two distinct regions—a region of *stars* lying principally in the plane of the Milky Way, and a region of *nebulæ* situated at right angles to it. This proves that the nebulæ undoubtedly belong to our sidereal system, and are probably for the most part no further removed than the average stellar distances; so that all the millions of stars revealed by the most powerful telescopes; the vast numbers of star clusters, each containing thousands of suns; the thousands of gaseous nebulæ; and even the Milky Way with its millions of orbs, form only the different parts of one huge and complex system—the sidereal universe.

THE MILKY WAY.

This luminous zone can be noticed on any dark and cloudless evening, as a beautiful band of soft light stretching completely across the heavens. Its position in the sky as seen in the northern and southern hemispheres can be easily found by means of the small circular charts at the end of the volume. In the northern heavens it will be noticed that the galactic zone passes near the constellations of Orion, Gemini, and Taurus, and completely traverses Auriga, Perseus, Cassiopeia, Cepheus, Cygnus, Vulpecula, Sagitta, Aquila and Serpens; and in the southern heavens, Ophiuchus, Sagittarius, Scorpio, Ara, Centaurus, Crux, and Argo, and passes exactly between the constellations of Canis Major and Canis Minor. That part of its course extending from Canis Major through Auriga to Cygnus, is comparatively faint and of fairly regular form. In Cygnus, however, the zone becomes broken up into several gaps, and before it enters Aquila it is completely divided into two streams, which continue till the constellation of Scorpio is reached, where it is once more united. From this part of the heavens to the place in Argo where the stream is completely separated by a curiously-shaped opening, its form is exceedingly complex, and at the same time its luminosity is more conspicuous. The Milky Way, or *Via Lactea,* thus passes completely round the star-sphere, and forms on it a luminous great circle, which proves that our sun is interior to it, and within its bounds.

In all ages this zone has attracted considerable attention, and offered for solution one of the noblest problems. For centuries the philosopher of old gazed at it in wonder and admiration, as night after night it moved over his head in its apparent revolution with the great star dome. Times without number the modern

PLATE 8A.



Gall & Inglis, Edinburgh.

THE SPIRAL NEBULA IN CANES VENATICI.

astronomer has turned his most powerful instruments to it, in the hope of sounding its mighty depths, for in it he knows there is locked the secret of the structure of the visible universe.

To the ordinary observer among the ancients, the Milky Way was simply a large mark in the heavens, which had been produced by the soldering together of the two hemispheres; a dense fire showing itself through a huge cleft in the celestial vault; or it was the home which the shades of happy souls inhabit. But while the multitude had no difficulty whatever in believing in these absurd imaginations, with the more enlightened minds it was greatly different. Though they did not possess, as we now do, the power of penetrating into many of Nature's greatest mysteries, and thus could not tell for a certainty of what the Milky Way was composed, or what importance it held in the sidereal universe, yet for all that they recognised the greatness of the problem that the more thoughtless had solved so easily, and rose to a not unworthy conception of its significance. They had, indeed, even concluded that it was composed of myriads of exceedingly faint stars. Manilius, their astronomical poet, advocates this remarkable idea—remarkable, indeed, for the time in which it was advanced; while the description given by Ovid might even have been the production of modern thought. He says:—

> "Its groundwork is of stars, through which the road
> Lies open to the Thunderer's abode."

But though the more advanced among the ancients might form even sublime ideas as to the nature of the Milky Way, yet, at best, their ideas could only be mere conjectures, for it required far more than man's ordinary vision to penetrate the mystery that was hidden within its bounds. It required, in fact, nothing less than a gift of second sight—a gift which, even three centuries ago, it would seem impossible for man ever to be able to possess. This wonderful gift has now been bestowed. Galileo, by his immortal invention, has enabled man to lift, in some measure, the veil which for long ages had obscured the wonders and beauties of the outside universe, and to look behind it far into the infinite depths of space, and see what was going on amongst the countless systems of suns and planets which surround us on every side.

It was not, then, until the newly-invented telescope had been turned to this great luminous zone, which had for so many centuries puzzled mankind, that its true nature was revealed. What Galileo saw, every one possessing even so small an optical instrument as an opera-glass, can see—viz., that the misty light of the Milky Way is in reality produced by the combined lustre of myriads of exceedingly faint stars. As the telescope rapidly improved, the structure of the Milky Way became more and more thoroughly examined. Sir W. Herschel was one of the first to make this grand star-stream the object of careful study. Sweeping it with his powerful reflectors, he penetrated to much vaster depths than any one before him had done, and even discovered the individual stars composing those faint clusterings, which with inferior instruments appear only as cloudy patches, like the Milky Way to the unaided eye. But even when all this had been accomplished, when mighty depths had been sounded and enormous numbers of orbs had been revealed, there still remained in the background other, though certainly smaller, parts which could not even with his most powerful telescope be completely resolved into stars.

The total number of stars distributed along the Milky Way must thus be so excessively great as to be altogether beyond our conception. On a photograph of a small portion of it recently taken by the author with a lens of not over four inches in diameter, and with an exposure of only three hours, more than one thousand stars can be counted; while, with one of Herschel's large reflectors, the number of stars was very great indeed. On one occasion, Herschel tells us, he allowed his instrument to remain stationary, so that the stars would, by the rotation of the earth, be made to pass through the field of view, and, in doing this, he found that, in so short an interval as one quarter of an hour, no less than one hundred and twenty thousand stars passed before his eyes; from which he concluded that there were, at least, *twenty millions* of stars in the Milky Way alone.

The stars composing this wonderful zone are evidently much smaller and lie at greater distances than the stars in other parts of the heavens. To Herschel, and others of his time, it seemed that this luminous belt was simply the effect produced by looking from near the centre towards the edge of a vast collection of orbs, and viewing great depths of stars; for it was supposed that these orbs were approximately of one size, and were fainter or brighter according to their difference of distance from our system. This, however, cannot by any means be the fact. The stars are, in many cases, not fainter or brighter owing to difference of distance, but to actual difference in size. Observation has now revealed to us that several of the brighter stars are removed to enormous distances, while one or two of the fainter orbs are comparatively near. Thus the Milky Way cannot receive its appearance from the combined light of large stars removed to enormous distances, but from a gigantic aggregation of comparatively small orbs.

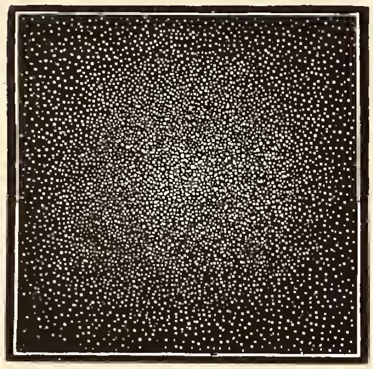
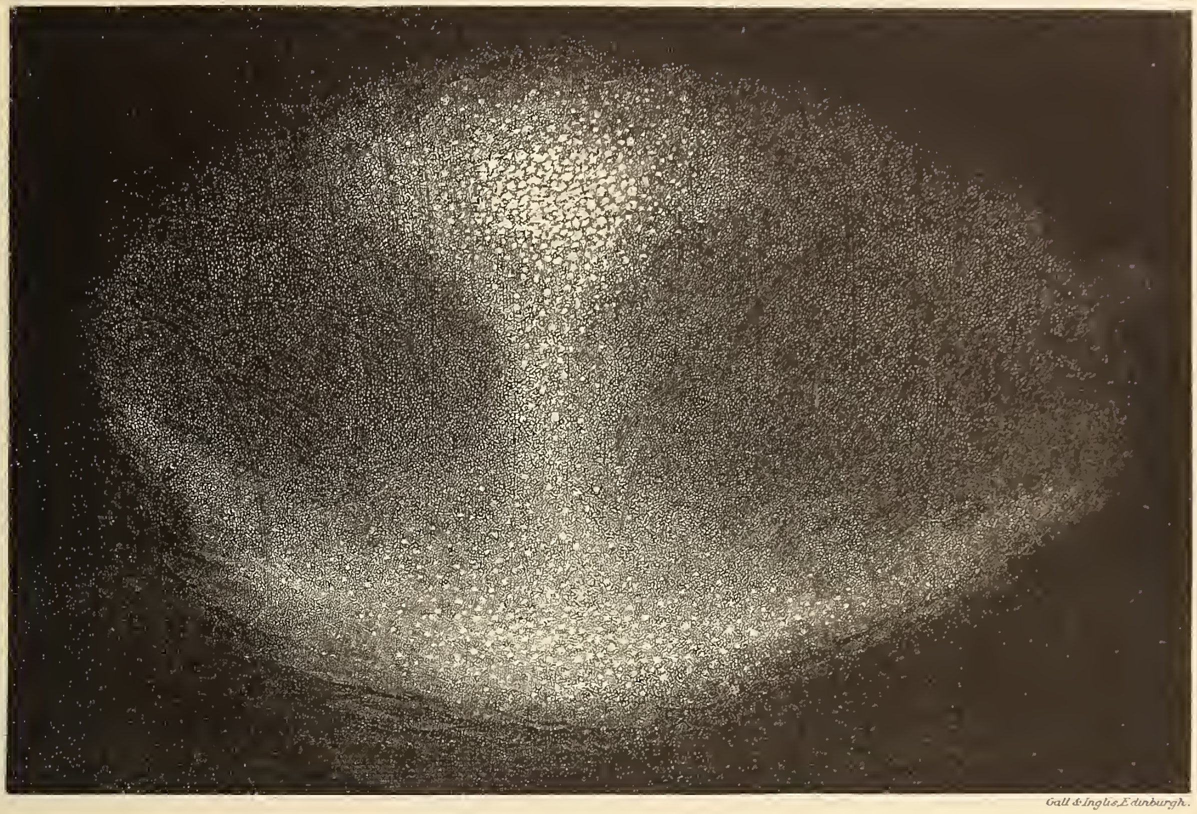


Fig. 15. THE MILKY WAY AS VIEWED WITH A TELESCOPE.

But though these orbs composing the Milky Way are apparently small, we must not on this account think that they are very insignificant, or, though seemingly close to each other, that they are so in reality. Each small twinkling point of light is a sun! a sun, it may be, not very much smaller than ours; and, though these suns are apparently touching, they are yet separated from each other by vast distances—distances that, in all probability, can only be reckoned by hundreds of millions of miles. Still further, these stars are not only suns—they are doubtless the centres of planetary systems; for as our sun, and each of the larger suns already considered, is the centre of a wonderful and extensive system of planetary globes, so is every one of the faint stars in the Milky Way the centre of a similar system of worlds. Each is, in fact, the centre of all force, all light, and all life to its system; upon whose munificent supplies the existence of intelligent beings may depend.

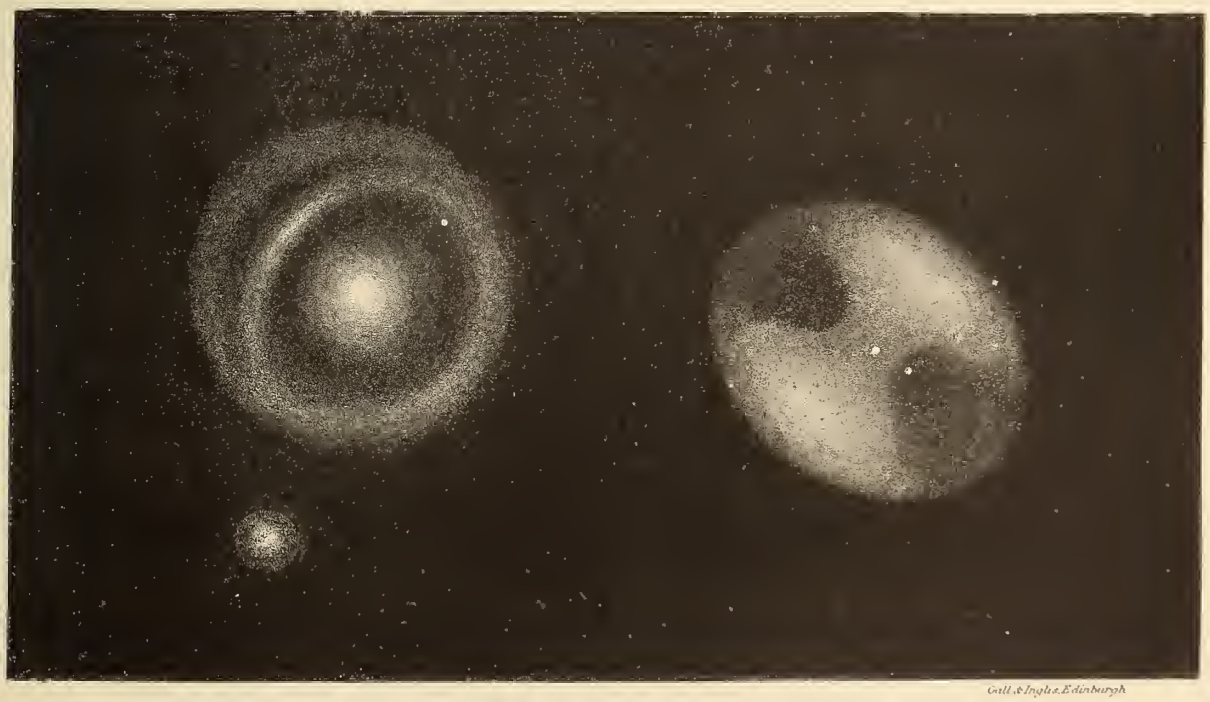
Looking at the Milky Way as it stretches across the heavens, and contemplating its grandeur, we are thus carried by imagination far from the busy scenes of earth, away into the mighty depths of space, amidst the splendour of suns and the rush of systems; and are led to think of the utter insignificance of the whole solar family, of our world which oftentimes seems so gigantic, and even of man himself, for we cannot believe that these glorious orbs have been called into existence for the purpose of rolling uselessly through endless space. Modern astronomy, by its wonderful discoveries, though unable to tell us directly that there are other inhabited earths besides our own, has certainly shown us that the universe is the production of one thought; that one plan runs throughout all that has been revealed. If, then, other suns and other earths have been created—as they have undoubtedly been—it is not altogether unreasonable to suppose that, as they have been produced by the same great laws as our own sun and our earth, they have been formed for similar purposes. A unity is thus recognised to exist between the most distant parts of space; yet along with this unity there is the most wonderful variety. Even in the whole sidereal universe, with its millions of millions of orbs, it is highly probable that no two are exactly alike. Each, certainly, has been formed under the same mysterious laws; on each the same forces and processes are at work; yet on each the outcome of these laws, these forces, and these processes may be greatly different; and so with Byron we say—

"Ye stars! which are the poetry of heaven!
. . . Ye are
A beauty and a mystery, and create
In us such love and reverence from afar
That fortune, fame, power, life, have named themselves a star."



Gall & Inglis, Edinburgh.

THE DUMB-BELL NEBULA AS SEEN BY LORD ROSSE.



Gall & Inglis, Edinburgh

NEBULAE AS SEEN BY SIR J. HERSCHELL.

CHAPTER IV.

THE SUN.

"Sire of the seasons! Monarch of the climes,
And those who dwell in them! for near or far
Our inborn spirits have a tint of thee,
Even as our outward aspects;—thou dost rise,
And shine, and set in glory."—*Byron.*

ITS DISTANCE FROM THE EARTH.

Till within comparatively recent times much error existed regarding the distance and size of the sun. Both of these are now known with certainty, and greatly exceed previous ideas. One of the first attempts to determine the true position which the sun occupies in the universe was made in the year 270 B.C. The philosopher Aristarchus of Samos, in that year, from observations of the moon when half enlightened, tried to measure the sun's distance, and though he was not so successful as might have been desired, he nevertheless increased the supposed boundaries of the universe, by proving that the sun was certainly much more distant and gigantic than the moon. About four hundred years afterwards, A.D. 138, the celebrated Alexandrian astronomer, Ptolemy, likewise attempted the measurement of the sun's distance, and concluded that it was considerably greater than Aristarchus had believed; stating its distance at about five millions of miles. This distance of Ptolemy's was considered so enormous that for over fourteen centuries afterwards it was believed to be approximately accurate. The first alteration of this distance was made by Kepler in 1618, who held that the sun was distant from the earth about fourteen millions of miles. In fact, by each attempt to measure the distance of the sun, it was proved that it was in reality greater than either the instruments or methods employed were capable of determining. The following Table shows the distance of the sun according to ancient astronomers.

DISTANCE OF THE SUN ACCORDING TO ANCIENT ASTRONOMERS.

DATE.	*ASTRONOMER.*	*DISTANCE.*	*DATE.*	*ASTRONOMER.*	*DISTANCE.*
270 B.C.	Aristarchus . .	3 millions of miles.	1543 A.D.	Copernicus . .	2 millions of miles.
130 B.C.	Hipparchus . .	3 " "	1602 A.D.	Tycho Brahe . .	5 " "
138 A.D.	Ptolemy . . .	5 " "	1618 A.D.	Kepler . . .	14 " "

It was not till the year 1672 that the more modern method of determining the distance of the sun, from the known distance of some planet nearer to us than that orb (such as Venus, or Mercury), was successfully employed. From numerous observations of the planet Mars, made in both hemispheres, the astronomer

Cassini found that the sun was distant from the earth at least eighty-five millions of miles, or actually six times further away than had been supposed from observations made by Kepler fifty-four years previously. But even this great increase of the ancient determinations is actually too small. From all the different methods that have been employed, it is now considered that the sun's true, average, or mean distance is very nearly

MODERN DETERMINATIONS OF THE SUN'S MEAN DISTANCE.

YEAR.	*ASTRONOMER.*	*METHOD OF DETERMINATION.*	*DISTANCE.*
1672 A.D.	Cassini, . .	From the parallax of Mars, ...	86,000,000 miles.
1770	Euler, . .	„ „ transit of Venus of 1769, ...	92,897,000 „
1771	Lalande, .	„ „ „ „ „	95,835,000 „
1772	Pingré, . .	„ „ „ „ „	92,790,000 „
1804	Laplace,. .	„ observations of the variation of the displacement of the moon, depending on the sun's distance, . . .	95,057,000 „
1814	Delambre, .	„ the transit of Venus of 1769, ...	95,613,000 „
1823	Enchi, . .	„ „ „ „ 1761 and 1769,. . . .	95,279,000 „
1832	Plana, . .	„ observations of the moon, ...	94,725,000 „
1862	Foucault, .	„ the measured velocity of light, ...	92,268,000 „
1864	Hansen,. .	„ „ displacement of the moon, ...	91,647,000 „
1867	Newcomb, .	„ „ parallax of Mars, ...	92,372,000 „
1872	Le Verrier, .	„ „ masses of the planets, ...	92,268,000 „
1875	Galle, . .	„ „ asteroid Flora, ...	92,163,000 „
1877	Cornu, . .	„ „ velocity of light, ...	92,897,000 „
1877	Airy, . .	„ „ transit of Venus of 1874, ...	93,321,000 „
1878	Stone, . .	„ „ „ „ „	92,060,000 „
1878	Tupman, .	„ „ „ „ „	92,372,000 „
1878	Maxwell Hall,	„ „ parallax of Mars, ...	93,002,000 „
1881	Puiseux, .	„ „ transit of Venus of 1874, ...	91,035,000 „
1888	......	„ „ British observations of the transit of Venus of 1882,	92,581,000 „
1888	......	„ „ American photographs „ „ „ „	92,372,000 „

92,897,000 miles—a distance that is probably accurate within 200 thousand miles. This distance is so enormous that an express train, travelling continuously at the velocity of sixty miles per hour, would require nearly 177 years to journey over it. Even light occupies a sensible interval in darting across this mighty void lying between us and the great centre of the system. Each minute this swift messenger journeys over a space of eleven *millions* of miles, yet the distance of the sun is so great that it requires no less than 8 minutes 19 seconds to travel from him to our earth.

SIZE OF THE SUN.

The distance of the sun being so enormous, proves that he is a globe of gigantic size. To all appearance he is about the same size as the moon, having an apparent diameter of about half a degree. His actual diameter will thus be as many times larger than that of the lunar globe as his distance from us is greater than that of our satellite. If, for instance as was once supposed, the sun's distance is only twenty times greater than that of the moon, then his diameter would only exceed the lunar diameter in the same proportion. The distance of the sun, however, is known to exceed the distance of our satellite over 387 times, and this will be the approximate proportion between the diameters of the two globes. The actual diameter of the solar globe is, therefore, no less than 866,500 miles —about 110 times greater than the diameter of the earth, or nearly twice longer than the diameter of the lunar *orbit*. The sun accordingly is an orb in size so gigantic that if the earth were placed in its centre, the moon could revolve in her orbit at her ordinary distance from us, and still be well within the solar globe (*see Fig.* 16). But if the difference between the solar and terrestrial diameters is striking, there is even a greater contrast between the surfaces and volumes. The surfaces of globes are in proportion, not to their diameters, but as the *squares*, and the volumes of globes, as the *cubes*, of their diameters. While, therefore, the diameter of the sun exceeds that of our globe 110 times, in surface it exceeds the earth twelve thousand, and in volume, or cubic capacity, one and a-third *million* of times.

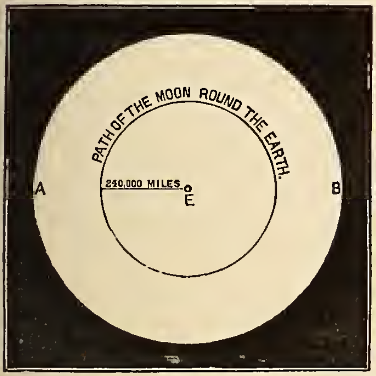


FIG. 16. DIAGRAM SHOWING RATIO OF THE ORBIT OF THE MOON TO THE DIAMETER OF THE SUN, A B.

If, however, the volume of the solar globe is so enormous, its comparative weight, or mass, is not so marked. Owing to the intensity of the heat, the materials of which the sun is composed are not nearly of so great a density as those forming our earth. The average density of terrestrial material is about five and a-half times that of water, but that of the sun, only one and a-half times.* While, therefore, one and a-third millions of earths would be required to form a globe equal to the sun in volume, 332 thousand only would equal the sun in mass. The *amount*, however, of this comparatively light material is so considerable, that, notwithstanding the great distance of the surface of the solar globe from its centre, the attraction of gravity on the surface is actually twenty-seven and a-half times greater than on earth, so that the weight we call a pound would, if removed to the solar surface, weigh twenty-seven and a-half pounds.† This increase of gravity on the sun's surface, in comparison with the attraction on our globe, notwithstanding that its distance from the centre is 110 times greater than in the case of our earth, shows that the total force of the sun is enormous; for the force, or attraction, of a globe is always in proportion to its mass. By it the various gigantic planets and comets of our system, as well as the tiniest meteorites, are kept revolving round this centre; moving in paths that in some cases are so wide that light occupies hours in journeying across them, and with velocities many times greater than that of a cannon-ball.

SUN-LIGHT AND HEAT.

Whilst the attraction of the solar orb is felt even at the remotest parts of the planetary system, if not among the nearer stars themselves, his light and heat will be influential there also. The quantity, or total amount, of light which the sun is constantly radiating into space is truly inconceivable. The intensity, however, or the comparative brilliancy of the solar surface with that of terrestrial luminous standards, can be approximately estimated. It is so great that even at a distance of 93 millions of miles, the sun actually appears 600 *thousand* times more brilliant than the full moon. In fact, it has been ascertained that, at the sun's surface, the light is no less than 90 thousand times brighter than a candle flame; five thousand times more brilliant than the dazzling radiance of molten iron; 150 times brighter than the lime-light; and three times more intense than the brightest attainable terrestrial light—the wonderful electric arc. The quantity and intensity of solar heat is likewise exceedingly great. It has been ascertained that during each hour every square yard of the sun's enormous surface radiates into space as much heat as could only be produced by the combustion of nine tons of coal; or to keep up the supply of solar heat it would require a shell of coal about twenty feet in thickness surrounding the sun, to be consumed every hour.

---

* The density of a globe, as compared with that of the earth, is determined by dividing the total quantity of matter it contains, or its mass, by its volume.

† The attraction of gravity on the surface of a globe is found by dividing the mass by the square of the distance from its surface to the centre—or by the square of its radius.

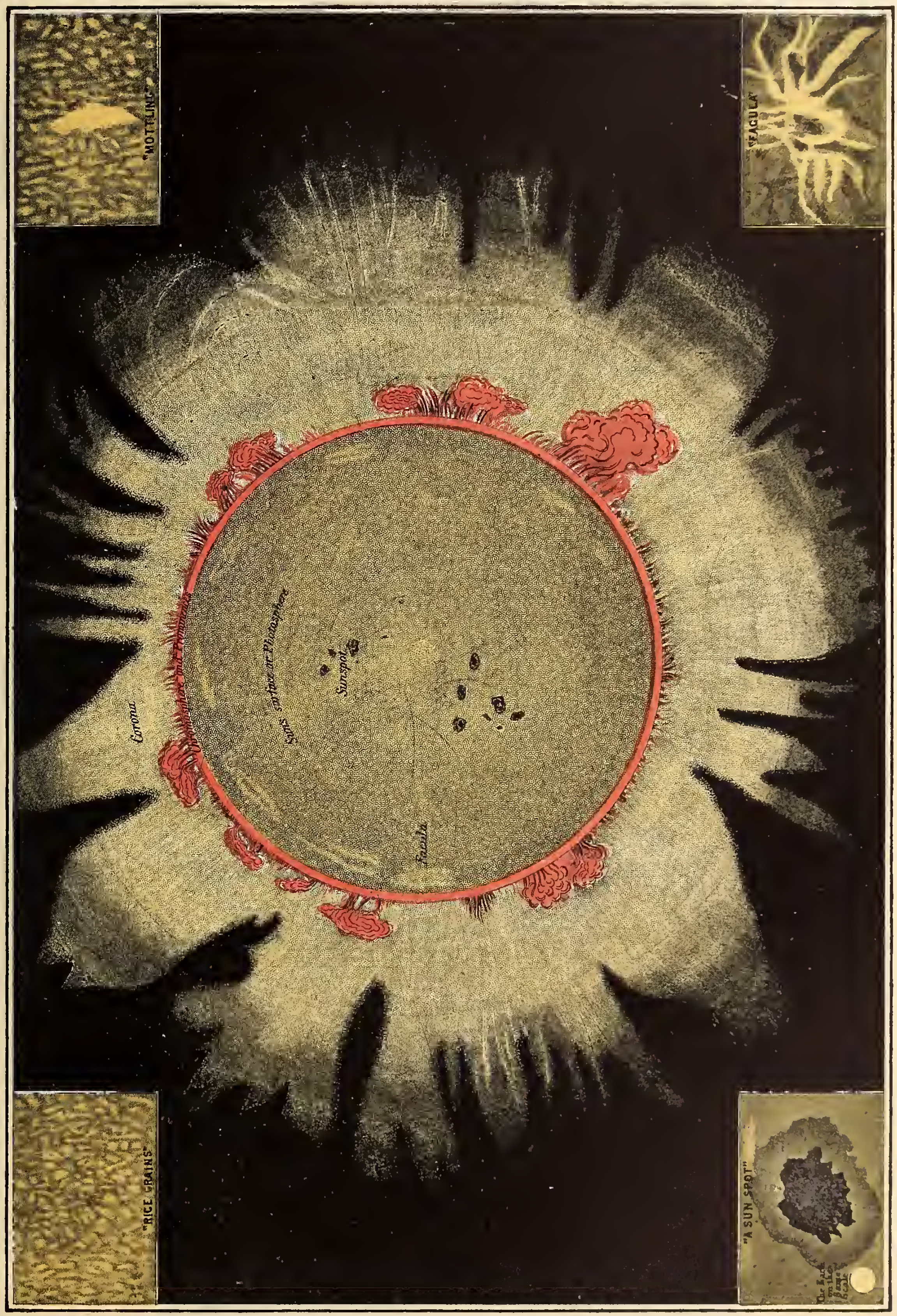
This vast quantity of light and heat constantly radiating from the sun into space cannot, as was formerly supposed, be maintained by any process of combustion. If the sun had been a huge ball of burning coal ignited six thousand years ago, it would by this time have burnt out and become a black mass. Neither can the maintenance of the light and heat be accomplished by the downfall of meteoric matter. If this were the case it would require as great a quantity of matter as there is in the moon, to fall into the sun every year. This amount of meteoric material, it is known, does not annually fall into the sun, so that it is neither by combustion nor by the precipitation of meteors that the solar light and heat are maintained. It is not, however, at all necessary that either of these processes should exist in order to supply the great loss of heat constantly taking place from radiation. By the mutual attraction of the gaseous particles of his globe, the sun has within himself the means not only of supplying what is lost by radiation, but of actually increasing his temperature. From the gradual contraction of his globe, enormous quantities of heat are being generated. Like all falling bodies whose forces are arrested, the various molecules composing the solar mass are, in being attracted towards the centre of the sun's globe, generating heat, and slightly more heat than is being radiated into space. In maintaining the supply of light and heat, the sun, from the contraction of its particles, is gradually decreasing in size. At present the yearly amount of subsidence of the vapours on the solar surface is thought to be about fifty yards, so that the diameter of the sun is annually decreasing by about one hundred yards. This decrease, however, cannot go on continually, but will sometime cease; then radiation will gradually cool the huge fiery globe, until it becomes a dark ball—a dead sun rolling through space.

SUN-SPOTS, ETC.

As soon as the telescope was directed to the sun it was discovered that his surface contained several dark spots. From a study of the manner of appearance and disappearance of these objects it was found that, like our earth, the sun rotated on his axis, and in the same direction, from west to east. It was noticed, however, that, unlike our globe, the sun does not turn all of a piece, but the more distant a part of the surface is from the solar equator, the slower its rotation. Near the equator, for instance, the rotation is accomplished in about twenty-five days; midway between the equator and the poles it is about twenty-seven days; while nearer the poles it is longer still. This proves that the sun's globe cannot be solid, but liquid, or rather vaporous, even to the centre.

It is noticed that the spots which apparently move across the solar disc from the rotation of his globe, are always confined to certain regions. Near the equator, spots are rarely noticed, and at the poles they are never seen, but seem located in two zones on the solar surface about twenty degrees in breadth, lying on either side of the equator. It is found, too, that the number of spots is not always, even approximately, the same. At times, no spots can be seen on any part of the surface, while at other times large numbers are visible. The number of spots, in fact, regularly passes from a maximum to a minimum, and back to a maximum again, in a period of about eleven years. This variation, which is simply an index of

THE SUN—PLATE 9.


"MOTTLING"
"FACULA"
Corona
Chromosphere and Prominences
Sun's surface or Photosphere
Sunspot
Facula
"RICE GRAINS"
"A SUN SPOT"
The Earth on the Same Scale

W. Peck Del.

Engraved by Archibald & Peck, Edin.

[illegible] Edinburgh

the variation of solar activity, is, strangely enough, in some way connected with the variation of the magnetic needle, for when the sun's activity is at a maximum, the diurnal movement of the compass is then greatest.

At first it was thought that sun-spots were simply quantities of slag or scoriae floating on the molten photosphere. Careful observations, however, have proved that this is far from being the case, as sun-spots are in reality enormous cavities. The blackness of a spot is produced by the light, which comes from the bottom of the cavity, being greatly diminished by absorption from the great depth of comparatively cool vapour with which the spot is filled. In fact, even the darkest part of the spot, or the *umbra*, is self-luminous, and shines with a brilliancy greater than that of the lime-light, and it is only by contrast with the exceedingly intense light of the surrounding surface that it appears dark. These spots, generally of an enormous size (*see Plate* 9), are continually undergoing great variation in shape and dimension. Within each spot, tremendous disturbances are continually taking place, the spots themselves being simply the outcome of the fierce cyclonic storms, which are always to some extent raging on nearly every part of the sun's gaseous surface. By means of these gigantic maelstroms, as revealed in the spots, the comparatively cool vapours of the surface are sucked far down into the interior, where they are heated, and, in the form of ejections, returned to the surface. This circulating action of the solar vapour is of the greatest importance in preserving the life and activity of the sun; for by it a solid crust is prevented from forming, and the solar globe from rapidly cooling down.

Besides dark parts or spots, there are portions which in appearance are considerably brighter than the general luminosity of the surface. These brighter portions are called *faculae* (*see Plate* 9). Unlike the spots, the *faculae* are seen on every part of the disc, but are more conspicuous near the sun's edge. This is owing to the effect of contrast, which is greater there, as the edge of the disc is considerably less brilliant than the centre. The *faculae* are believed to be nothing more than gigantic eruptions of comparatively light, but much more intensely-heated vapour, such as glowing hydrogen, which are momentarily taking place on all parts of the surface. Seen with very high telescopic powers the disc has a peculiarly granulated or mottled appearance. The largest markings are known as *rice-grains,* and the small ones as *granules.* Like the *faculae,* but on a very much smaller scale, these markings seem to be clouds of intensely hot and bright gases suspended in a slightly darker atmosphere.

THE SUN'S INTERIOR.

That portion of the sun from which we receive our light—the visible surface, or the *photosphere*—is simply a shell of glowing vapour about 10,000 miles in thickness. Below this region there is the gigantic central ball of the sun, 850,000 miles in diameter, about which astronomers know little or nothing, beyond the fact that it cannot be solid. From the intensity of the internal heat, it is known that even the centre of the sun or the densest part of the solar globe, notwithstanding the enormous pressure to which the particles composing it are subject, consists of some gaseous material, though the vapour there is doubtless, from the pressure, as heavy as the densest of our metals.

SOLAR ATMOSPHERE.

Lying immediately above the photosphere, and extending outwards to an unknown distance, is the sun's so-called atmosphere. This atmosphere, completely surrounding the solar globe, is in nature exceedingly complex. Its base, extending from the visible surface for about one thousand miles, is chiefly composed of the heavier metallic vapours, such as the vapour of iron, copper, zinc, &c. Above this layer the uncondensed gases are much lighter, and consist principally of hydrogen. This part extends upwards to about 10,000 miles, and from its coloured appearance is called the chromosphere. In it the most wonderful changes are ever taking place. Eruptions are constantly projecting monster jets of hydrogen gas, mixed with metallic vapour, to great heights, sometimes to over 100,000 miles. Generally these *prominences,* as they are designated, are of a blood-red colour, and can only be seen either by aid of the spectroscope, or during a total solar eclipse.

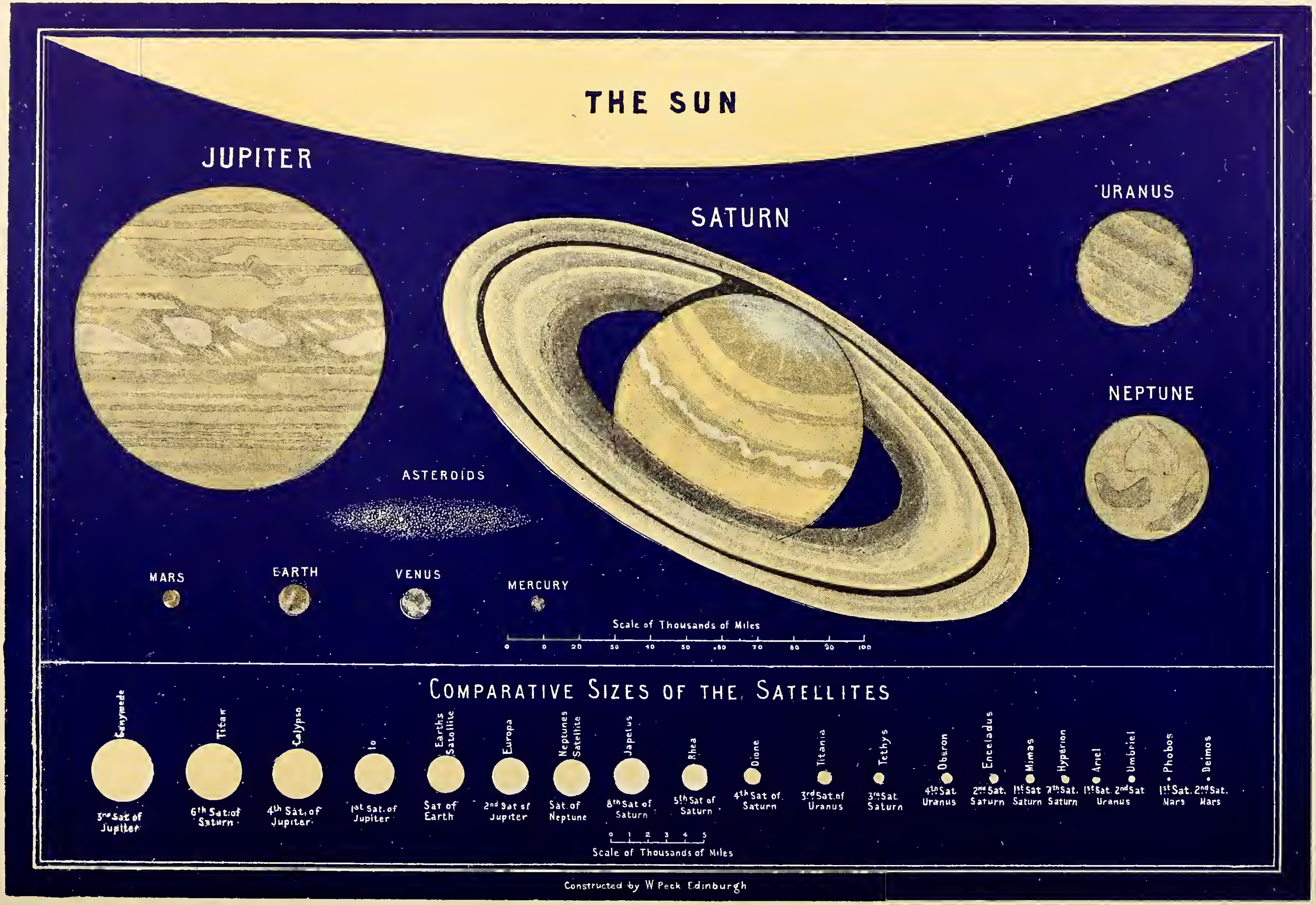
Beyond this region the so-called outer atmosphere begins. This is also well seen when the brilliant disc of the sun is hidden by the moon in an eclipse. In appearance it resembles a crown of glory surrounding the apparently extinguished sun, from which it has been called the "corona." The material of which the coronal part of the solar atmosphere is composed is exceedingly light, and is doubtless of a very complex nature. The inner part, extending to about 300,000 miles from the visible surface, is thought to be principally gaseous, its material being chiefly formed by the gigantic eruptions, which carry vast quantities of vapour to enormous heights. The outer part, on the other hand, is believed to be largely composed of solid particles, and is thus likely to be of meteoric origin—being probably produced by the materials of dissipated comets and meteor streams drawn towards the sun by his mighty attraction, and caused to shine, partly by inherent light from the sun's intense heat, and partly by reflecting the sun-light.

But though the corona does not apparently extend much beyond 300,000 miles from the sun, as observed in solar eclipses, it has nevertheless been traced to a considerably greater distance. The rarer, and more distant portion, extends, in fact, so far from the sun as to appear in the sky long after sunset, or before sunrise, and is known as the zodiacal light. Indeed, this portion of the sun's atmosphere has been noticed extending from the sun to a distance of no less than about 100 *millions* of miles—a distance greater than that which separates the earth from the gigantic centre of the solar system. Very probably, however, it reaches even to the path of the most distant planet; so that not only our earth, but each member of the system, in its orbital journey, moves through part of this mighty envelope which surrounds the sun. By it the motions of the various orbs will be slightly retarded, and drawn gradually nearer to the centre, until ultimately they become united with the sun himself.

PRINCIPAL FACTS ABOUT THE SUN.

The mean distance of the sun, which is employed throughout this work, . . .	92,897,000 miles.
Nearest distance of the earth from the sun (in January), ...	91,347,000 „
Greatest distance of the earth from the sun (in July), ...	94,447,000 „
The variation of the earth's distance from the sun thus amounts to	3,100,000 „
Length of the sun's actual diameter, ...	866,500 „
Proportion between the diameter of the sun and that of the earth, ...	110 to 1.
Surface of the sun compared with that of the earth, ...	12,000
Volume, or cubic contents, of the sun compared with the earth, ...	1,300,000
Mass, or quantity of matter, of the sun compared with the earth, ...	332,000
Average density of the solar globe compared with that of the earth, ...	0·255.
Average density of the solar globe compared with that of water, ...	1·41.
Attraction of gravity on the sun's surface compared with that on the earth, . . .	27·6.
Inclination of the axis of the solar globe to the plane of the earth's orbit, . . .	82° 45′.
Period of the sun's rotation at the equator, ...	25 days.
„ „ „ „ latitude 20°, ...	25·75 days.
„ „ „ „ „ 30°, ...	26·5 „
„ „ „ „ „ 45°, ...	27·5 „
Linear velocity of the sun's equator per second, ...	1·26 miles.

PLATE 10—THE COMPARATIVE SIZES OF THE PLANETS.


THE SUN
JUPITER
SATURN
URANUS
NEPTUNE
ASTEROIDS
MARS
EARTH
VENUS
MERCURY
Scale of Thousands of Miles
0 10 20 30 40 50 60 70 80 90 100
COMPARATIVE SIZES OF THE SATELLITES
Ganymede
3rd Sat of Jupiter
Titan
6th Sat of Saturn
Calypso
4th Sat of Jupiter
Io
1st Sat of Jupiter
Earths Satellite
Sat of Earth
Europa
2nd Sat of Jupiter
Neptunes Satellite
Sat of Neptune
Japetus
8th Sat of Saturn
Rhea
5th Sat of Saturn
Dione
4th Sat of Saturn
Titania
3rd Sat of Uranus
Tethys
3rd Sat Saturn
Oberon
4th Sat Uranus
Enceladus
2nd Sat Saturn
Mimas
1st Sat Saturn
Hyperion
7th Sat Saturn
Ariel
1st Sat Uranus
Umbriel
2nd Sat Uranus
Phobos
1st Sat Mars
Deimos
2nd Sat Mars
0 1 2 3 4 5
Scale of Thousands of Miles

Constructed by W Peck Edinburgh

CHAPTER V.

THE PLANETARY SYSTEM.

"World beyond world, in infinite extent,
Profusely scattered o'er the void immense,
Show me their motions, periods, and their laws."—*Thomson.*

As mentioned in the last chapter, the sun occupies the centre of the planetary system, producing and regulating the movements of all orbs lying within the sphere of his mighty attraction, and bountifully supplying them with his light and heat. These orbs, revolving round him, constitute the solar family, which consists of eight large planets and numerous smaller ones, divided into distinct classes, revolving in orbits widely separated from each other. The eight principal orbs are separated into two groups, which may be designated inner and outer planets; while revolving between these are the tiny orbs of the system—the asteroids, or small planets. The planet lying immediately outside the orbit of our earth is the most distant member of the inner group from the sun—the planet MARS; while the nearest member of the outer planets—JUPITER—is situated at a distance from the central orb no less than five times that of the earth. In the order of their distances from the sun, the inner planets are MERCURY, VENUS, THE EARTH, and MARS; and the outer planets, JUPITER, SATURN, URANUS, and NEPTUNE. There are, therefore, in the planetary system, three different groups of orbs. First, there is the inner, or terrestrial group, from MERCURY to MARS, of which our earth is the largest member; second, the small planets, or asteroids, revolving between the orbits of MARS and JUPITER; and third, the outer, or giant planets, from JUPITER to NEPTUNE, of which JUPITER is by far the largest.

Amongst the various members of these classes of planets there exists the most striking difference, in dimensions, in weight, and in condition. JUPITER, for instance, exceeds our earth, the largest of the inner planets, no less than 1300 times in volume, and is actually larger and heavier than all the other planets put together. In a greater proportion even, our globe exceeds the largest of the asteroids (*see Plate* 10). In density, or comparative weight of material, there is likewise a marked contrast. The average density of the inner planets (about five times greater than that of water) is much greater than that of the outer orbs. The outer planets, on the other hand, are, on the average, about the same density as that of water. With regard to the velocity of rotation, there is also a considerable difference. Notwithstanding their enormous size, the outer planets rotate very rapidly; while the inner orbs perform their rotations in comparatively slow periods. But even in their present physical constitution there exists a marked contrast. The members of the inner group are chiefly solid globes, which, from their comparatively insignificant dimensions, have long since cooled from their former hot and molten condition, and are rapidly approaching that stage in each orb's existence that may be called planetary old age. The outer planets, on the other hand, are mostly red-hot masses, surrounded by dense atmospheres, and fitly represent planetary youth, or the fiery condition of an orb before radiation has accomplished the process of cooling.

THE PLANETS NEAREST THE SUN.

Though MERCURY is undoubtedly the nearest large planet to the sun, several other orbs are believed to revolve within his path. No less than twenty of these intra-Mercurial planets are recorded as having been seen crossing the sun's disc in transit as dark spots. As, however, the observers of these supposed orbs have not, in most cases, been experienced astronomers, the so-called discoveries have been rejected. The largest of these planets has been called VULCAN. It was believed to have been seen crossing the sun's disc in the year 1859; but if this had really been the case it ought to have been noticed shining as a star during every subsequent total solar eclipse. This has not been the case. During each total eclipse of the sun since the year 1859, careful search has been made for the planet, and yet it has not been observed, a fact which clearly proves that VULCAN does not really exist.

But if a large planet, such as VULCAN was supposed to be, does not revolve between MERCURY and the sun, several very small orbs, interior to the path of MERCURY, have been discovered. These have not been seen as in the case of VULCAN, crossing the solar disc in transit, but have been detected on several occasions, as small stars shining near the sun when totally eclipsed. The orbs thus discovered are believed to be the largest members of a small ring of tiny planets, somewhat like the so-called ring of asteroids revolving between the orbits of MARS and JUPITER.

MERCURY.

"Thou little sparkling star of even,
Thou gem upon an azure heaven!"—*Maria Davidson.*

MERCURY, then, is the first important planet outward from the sun. Owing to his proximity to the solar orb it is extremely difficult to perceive this planet, as he is nearly always hidden by the overpowering brilliancy of the sun's rays. Being nearer the sun than our globe, his path is considerably smaller than the orbit of the earth. In fact, the path of MERCURY is so much smaller than the terrestrial orbit, that if he journeyed only at the same velocity as our globe, or at about eighteen miles per second, he would accomplish his revolution in about 141 days. The motion of the planet in its orbit, however, is much more rapid than in the case of our earth, and, therefore, a revolution is completed in 88 days, which is the length of this planet's short year.

The distance of the planet from the sun, notwithstanding the rapidity of its revolution, is considerable. On the average it is situated at a distance of about thirty-six millions of miles. As indicated in Plate 11, the planet's orbit is not circular, but very elliptical, more so, indeed, than that of any other large planet. This ellipticity of the path is in fact so great, that, when traversing one part of it, MERCURY is actually fifteen millions of miles nearer the central orb than when moving at the diametrically opposite part. When nearest to the sun his distance is twenty-eight and a-half millions of miles, while it is increased to forty-three and a-half millions when at his farthest from the sun. On account of this great variation of distance from the centre of attraction, there results a considerable range of orbital velocity. When moving in *perihelion*, or in that part of his path which lies nearest to the sun, the planet's velocity is no less than thirty-five miles per second; while, when moving at his greatest distance from the solar orb, or at *aphelion*, it is reduced to about twenty-three miles per second.

The supply of light and heat which the planet receives from the sun, varies in even a greater proportion. The amount of light and heat does not decrease directly as the distance from the luminous source increases, but as the *square* of the distance. While, therefore, MERCURY, from being nearer to the sun than our globe, receives on the average seven times more light and heat than is received by the earth, yet, from the great alteration of his distance, this quantity is subject to a variation in the proportion of nine to four.

MERCURY is the smallest member of the inner planets. His diameter is only two-fifths of the earth's, or about three thousand miles. The surface of his globe is thus only one-seventh of the terrestrial surface, and his volume about one-eighteenth. Therefore, MERCURY is a globe eighteen times smaller than ours, and only three times larger than the moon. The materials, however, of which he is composed, are much heavier than those forming our earth, or, indeed, of any other planet in the system. In fact MERCURY is, curiously enough, about the same weight as if he were formed solely of metal of the same name; for his density is believed to be about two and a-half times greater than that of our globe, or about twelve times greater than the density of water. MERCURY, then, while being the smallest of the primary planets, is, in proportion to his dimensions, by far the heaviest of them. In size he is only about one-eighteenth of the terrestrial globe, while in total weight, or mass, he is actually one-eighth of the mass of the earth.

When this small planet is examined with a telescope it is found, when revolving round the sun, to undergo all the phases of the moon (*see Plate* 15). When close to the sun, and nearer to us than that luminary, it appears as a slender crescent. Each day as the planet, from its orbital motion, travels to the westward of the sun's disc, this brilliant crescent increases in breadth, till, when at its greatest apparent distance from the sun, it is seen as a half-illuminated disc. From this position, the greatest western elongation, the planet now appears gradually to approach the solar orb. Its distance from the earth increases and its apparent diameter becomes in consequence smaller and smaller, and at the same time more of its lighted side is directed towards our globe, till it arrives once more near the solar disc. When further away from us than the sun it appears as an exceedingly small and perfectly round disc. This position is called *superior* conjunction, which is exactly opposite to that part of the orbit occupied by the planet when exactly between us and the sun, or at *inferior* conjunction. When in this latter position it sometimes happens that the planet is likewise not very distant from the node of its orbit, or that part of its path which cuts the ecliptic plane. From being then situated on nearly the same level as the solar globe and the earth, it can be seen projected on the sun's disc, and observed to move across, or transit, the sun as a dark spot. The transits of Mercury which have taken place since the first one was observed, as also those which will occur till the end of the next century, are as follow :—

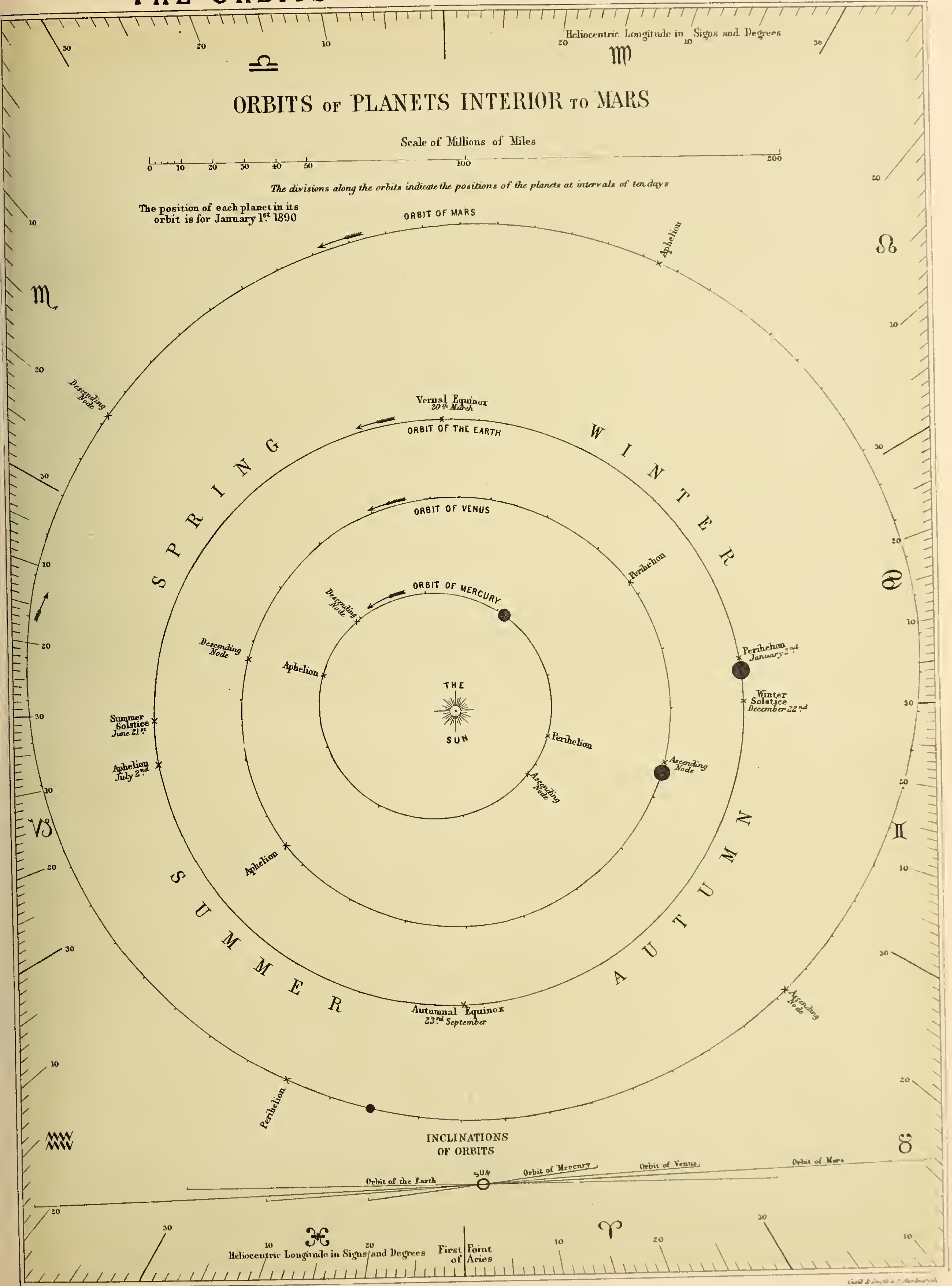
TRANSITS OF MERCURY.

THOSE THAT ARE MARKED WITH AN ASTERISK HAVE NOT BEEN OBSERVED.

YEAR.	*MONTH.*	*YEAR.*	*MONTH.*	*YEAR.*	*MONTH.*	*YEAR.*	*MONTH.*
		*1710	Nov. 6	1802	Nov. 9	1907	Nov. 12
		1723	Nov. 9	*1815	Nov. 12	1914	Nov. 6
		1736	Nov. 11	1822	Nov. 5	1924	May 7
		1740	May 2	1832	May 5	1927	Nov. 8
1631	Nov. 7	1743	Nov. 5	1835	Nov. 7	1937	May 10
*1644	Nov. 8	1753	May 6	1845	May 8	1940	Nov 12
1651	Nov. 2	1756	Nov. 6	1848	Nov. 9	1953	Nov. 13
1661	May 3	1769	Nov. 9	1861	Nov. 12	1960	Nov. 6
*1664	Nov. 4	*1776	Nov. 2	1868	Nov. 5	1970	May 9
1677	Nov. 7	1782	Nov. 12	1878	May 6	1973	Nov. 9
1690	Nov. 10	1768	May 4	1881	Nov. 8	1986	Nov. 12
1697	Nov. 3	1789	Nov. 5	1891	May 9	1999	Nov. 24
1707	May 6	1799	May 7	1894	Nov. 10		

The most noticeable feature in all telescopic views of Mercury is the marked irregularity of the terminator or boundary between the light and dark part. This proves that the surface of the planet cannot be smooth, but broken up by numerous mountains. Even a more wonderful discovery, however, has been made. Like our earth, Mercury has been found to be surrounded with an extensive atmosphere, which contains large quantities of watery vapour. This clearly indicates the presence of water on the surface of the planet; so that besides mountains, there are oceans and continents. Still further, it is not improbable that some form of life exists there.

THE ORBITS OF THE INNER PLANETS—PLATE 11.


ORBITS OF PLANETS INTERIOR TO MARS
Scale of Millions of Miles
0 10 20 30 40 50 100 200
The divisions along the orbits indicate the positions of the planets at intervals of ten days
The position of each planet in its orbit is for January 1st 1890
Heliocentric Longitude in Signs and Degrees
♎ ♏ ♌ ♋ ♊ ♉ ♈ ♓ ♒ ♑ ♐
ORBIT OF MARS
Aphelion
Descending Node
Ascending Node
Perihelion
Vernal Equinox 20th March
ORBIT OF THE EARTH
ORBIT OF VENUS
ORBIT OF MERCURY
SPRING
WINTER
SUMMER
AUTUMN
Perihelion January 2nd
Winter Solstice December 22nd
Summer Solstice June 21st
Aphelion July 2nd
Autumnal Equinox 23rd September
THE SUN
INCLINATIONS OF ORBITS
SUN
Orbit of the Earth
Orbit of Mercury
Orbit of Venus
Orbit of Mars
First Point of Aries
10 20 30

Engraved by Archibald & Peck Edinr.

VENUS.

'Fairest of stars, last in the train of night,
If better thou belong not to the dawn,
Sure pledge of day, that crown'st the smiling morn
With thy bright circlet, praise him in thy sphere."—*Milton.*

THIS planet is, to the unaided eye, the most beautiful of all the heavenly bodies. In ancient times it attracted considerable attention, and centuries before the true system of the universe was recognised, its curious movements among the stars had been carefully observed. As these movements came to be noted, it was found that the bright evening star (which was called *Hesperus* or *Vesper*) was not always visible, but made its appearance at regular intervals. When first detected it was invariably situated in a part of the heavens very near to the sun's bright disc. Each evening it travelled farther and farther away from the solar orb, till it reached a certain distance from him. It then began gradually to approach the sun, becoming at the same time brighter and brighter, till it finally travelled so close to him as to become lost in his brilliant rays.

But while a conspicuous evening star appeared in the western sky at regular intervals, there was also seen, from time to time, a brilliant morning star. This orb (which received the name of *Lucifer* or *Phosphorus*) behaved itself in a manner similar to HESPERUS, only its movements, with respect to the sun, seemed to be performed in reversed order. Instead of being visible in the western sky, and setting after the sun, it was seen in the east before the solar orb had yet appeared. When first it became visible it was always exceedingly brilliant, and, like the evening star, it was situated very close to the solar globe. Like HESPERUS, too, it was noticed from day to day to be more and more distant from the sun, till it reached its farthest, then began to return to the position it occupied when first detected shining amidst the solar rays.

Now, as these conspicuous stars, *Hesperus* and *Lucifer*, began to be more carefully observed, it was found that when the former was visible in the evening, the latter was invisible in the morning; and on the other hand, when *Lucifer* was seen in the morning, the bright evening star, *Vesper*, had disappeared. Accordingly, it came to be discovered that what had hitherto been called two separate stars were simply different appearances of one and the same planet. This planet was also named the "Shepherd's Star," but it is now better known by the name given to it by those who, recognising its superior brilliancy and beauty among the "host of heaven," called it after their most beautiful divinity—VENUS.

The brilliancy of this planet, as already mentioned, is such as to surpass all the other stars in the heavens. This being so, one would imagine that, of the eight orbs which circle round the central globe, this one would undoubtedly be among the largest. Such, however, is far from being the case; VENUS is a globe not quite so large as our earth. Her brilliant light, which makes her so conspicuous, is only borrowed; as, like our own planet, she is a dark globe shining only by the light of the sun.

As VENUS revolves round the "central orb" in a path interior to the orbit of the earth, the year there will be much shorter than ours. In fact, the time occupied by this planet in making a complete revolution round the sun is scarcely 225 days, or about seven and a-half months. Her distance from the sun is about sixty-seven millions of miles, which is a little less than three-fourths of the distance which separates that luminary from our globe. The day there is also less than ours, being about twenty-three hours and twenty-one and a-half minutes, so that there are over 230 days in the year of VENUS. As the axis of the planet is inclined to her path, there will take place there, as on earth, all that wonderful variety of the seasons. Her year, however, being shorter than ours, each season can last for scarcely two of our months.

This beautiful planet, then, is in many respects a world such as ours. It has its year and its seasons. It rotates on its axis, and thus has days and nights, and it is a globe approaching very nearly ours in size—its diameter being only about 200 miles less than the diameter of the earth. It is, however, not quite so heavy a globe as the earth, as the materials forming it are somewhat lighter than those composing our world. In one respect Venus is greatly inferior to our globe, in the fact that she has no attendant planet or satellite.

The heat of the sun on this planet must be excessive, for the solar heat is there twice stronger than on earth. It will, however, be considerably tempered by the dense clouds which float in the air surrounding the planet, as it has been found that Venus has even a more extensive atmosphere than our earth. The effects of this air surrounding the planet have been seen very plainly on several occasions. Like Mercury, Venus sometimes comes between us and the sun, at her inferior conjunction, and passes directly in front of the solar globe. When this takes place, the planet is seen to travel from left to right, as a black spot across the sun's bright disc. It was thus seen to move over, or to "transit," the solar disc in 1874, and again in 1882, but there will not be another till the year 2004, as will be seen from the Table. When Venus is just appearing to enter on the solar disc, a ring of brilliant light is seen surrounding that side of the planet which is farthest from the sun; and the same phenomenon is again observed when part of the planet has passed off the sun's face. This ring of light is caused by the air surrounding the planet bending the solar rays towards the earth, and bringing them into view. Now, as this ring of light is exceedingly brilliant, it shows that there must be a large quantity of sunlight bent, or refracted, towards us, which again proves that the atmosphere of Venus must be very dense. This atmosphere, like Mercury's, contains large quantities of watery vapour, which implies the existence of large tracts of water on the globe of the planet.

TRANSITS OF VENUS.

DATE.	*REMARKS.*	
1631. December 7	Not observed	at ascending node.
1639. „ 4	Observed by Horrox and Crabtree	
1761. June 5	Observed in various parts of the world	at descending node.
1769. „ 3	„ „ „	
1874. December 9	„ „ „	at ascending node.
1882. „ 6	„ „ „.	
2004. June 8		at descending node.
2012. „ 6		

On the surface of Venus there have been detected very high mountains. Oceans and continents are also there, and very probably inhabitants. In fact, at present, Venus is probably the only inhabited planet in the solar system besides our earth. True, the heat of the sun must there be very scorching, but this may not be any drawback whatever to the existence of living creatures. On earth we find that all life is constituted for the position in which it is placed—whether that position be the barren and frozen regions surrounding our poles, or the scorching wastes near the equator. Accordingly, if life exists on Venus, it will, without doubt, be adapted to its surroundings. If some of these beings are intelligent, and capable of thinking like man, they cannot fail to notice, shining at night in their moonless skies, a brilliant star (our earth) with a small companion star (the moon) near it. From observations they will find that the small star revolves regularly round the large one; that the large star is like their own globe—a planet moving round the sun; and while they gaze at it they will doubtless wonder if that distant orb, with its tiny companion, can be, like their world, the home of intelligent beings; or if their globe alone, of all the "countless host of heaven," is the only abode of intelligent life.

THE EARTH.

"Like the baseless fabric of this vision,
The great globe itself,
Yea, all which it inherits, shall dissolve."—*Shakespeare.*

THE earth is the largest of the inner planets, being nearly equal to the combined volumes of MERCURY, VENUS, and MARS. Her mean or average diameter is very nearly 7918 miles in length, so that her surface contains no less than about 197 millions of square miles. In shape our planet is not truly globular, but slightly elliptical, the larger or equatorial diameter being about twenty-five miles longer than the diameter from pole to pole. Accordingly the polar diameter amounts to 7901·6 miles, and the diameter from opposite points of the equator to 7926·6 miles. Owing to this ellipsoidal form the degrees of latitude, which would be of the same length on every part of the earth if her form were spherical, increase in size as they recede from the equator.

LENGTH OF A DEGREE OF LATITUDE AT DIFFERENT DISTANCES FROM THE EQUATOR.

LATITUDE,	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°
LENGTH OF A DEGREE IN MILES,	68·70	68·72	68·78	68·83	68·98	69·11	69·22	69·31	69·36	69·39

As in volume, the terrestrial globe is also in total weight or mass about equal to the combined weights of the other members of the inner group of planets. From numerous observations of the attractive influence of the earth, it has been determined that this weight amounts to no less than 6,000,000,000,000,000,000,000 of tons. Accordingly the average density, or comparative weight, of the terrestrial material is about five and a-half times greater than that of water; or it would require five and a-half globes the same size as ours composed of water, to equal the earth in weight.

Like the other members of the planetary system the earth moves round the sun in a path that deviates slightly from a true circle (*see Plate* 11). As explained in Chapter VI., the sun does not occupy the centre of this elliptical curve, but one of the two points in it called the foci. The distance of our globe from the centre of her movement, is, in consequence, subject to a considerable variation. In fact, throughout an entire revolution this alteration of distance from the sun amounts to no less than about three millions of miles. At the beginning of January, for instance, when the earth is nearest to the sun, or in *perihelion*, the distance amounts to 91,336,000 miles; while at the commencement of July, when our globe is in the opposite part of her orbit, or in *aphelion*, the distance is increased to 94,458,000 miles. The velocity of the earth in traversing her orbit, which, on the average, is about eighteen and a-half miles per second, is likewise subject to variation. Owing to the laws of gravitation, the nearer a heavenly body is to the governing mass, the greater becomes its orbital velocity. In the case of our globe this variation of speed throughout the year, from the ellipticity of the terrestrial orbit, amounts to over half-a-mile per *second*, or in the proportion of 61 to 59.

The distance of the sun from the centre of the elliptical orbit of a planet, in proportion to the planet's mean distance from the central orb, or to the length of the semi-major axis of the path, is termed the eccentricity of the orbit—the amount of the sun's displacement from the centre. As already mentioned, the terrestrial orbit differs but slightly from a true circle, the eccentricity being about one-sixtieth (·0168) of the sun's average distance, or the sun is distant from the centre of her orbit 1,560,000 miles. As in the case of every other planet, the eccentricity of the earth's orbit is subject, throughout long periods, to a considerable variation. This change of ellipticity produces an alteration of the supply and distribution throughout the year of light and heat received from the sun, thus affecting the temperature and climates of our globe, and having in the past, in all probability, been the principal cause of the different glacial epochs.

THE ECCENTRICITY OF THE TERRESTRIAL ORBIT FOR 200,000 YEARS.

YEAR B.C.	*ECCENTRICITY (expressed as a fraction of the semi-major axis).*	*LONGITUDE OF PERIHELION.*	*YEAR A.D.*	*ECCENTRICITY (expressed as a fraction of the semi-major axis).*	*LONGITUDE OF PERIHELION.*
100,000	0·0473	316° 18′	0	0·0168	99° 30′
90,000	0·0452	340° 2′	10,000	0·0115	134° 14′
80,000	0·0398	4° 13′	20,000	0·0047	192° 22′
70,000	0·0316	27° 22′	30,000	0·0059	318° 47′
60,000	0·0218	46° 8′	40,000	0·0124	6° 25′
50,000	0·0131	50° 14′	50,000	0·0173	38° 3′
40,000	0·0109	28° 36′	60,000	0·0199	64° 31′
30,000	0·0151	25° 50′	70,000	0·0211	71° 7′
20,000	0·0188	44° 0′	80,000	0·0188	101° 38′
10,000	0·0187	78° 28′	90,000	0·0176	109° 19′
0	0·0168	99° 30′	100,000	0·0189	114° 5′

The interval occupied by our globe in making a complete revolution of her orbit is termed the year. This is of different lengths, depending on the manner in which it is determined. If, for example, the interval observed be the one occupied by our globe in returning to the same part of her orbit with respect to a star, it is equal to the true period of the earth's revolution round the sun. This period is called a *Sidereal Year*, or year determined from the stars, whose length is 365 days 6 hours 9 minutes 9 seconds. While, however, this is the only true year, it is not, as might have been supposed, the one that is employed chronologically. The calendar being arranged according to the seasons, and as these entirely depend on the position of the sun, the *Solar, or Tropical Year* is the one generally used. It is about twenty minutes shorter than the sidereal year. Owing to the swaying of the earth's axis, or the precession of the equinoxes, the return of the sun to the same tropic, or to the equator, takes place *sooner* than the interval occupied by our globe in making a complete orbital revolution. Accordingly the tropical year is only 365 days 5 hours 48 minutes 46 seconds in length. But there is yet a third year, one determined by the return of the earth to the same part of her path. If the orbit of our globe were stationary this latter year would be of exactly the same length as the sidereal year. The axes of the orbit, however, as will be seen from the above Table containing the position of the perihelion for different epochs, are not fixed, they, on the contrary, slowly move round the sun towards the east, or in the same direction as that in which the earth journeys, and complete a revolution in about 108 thousand years. From this movement the earth, before returning to the same part of her path, has to accomplish more than a complete period of revolution, as during the interval the point on the orbit has moved forward in the same direction as our globe. The interval, therefore, between two successive returns to the same part of the orbit (the perihelion, or aphelion, for instance) is longer than even a sidereal year. It is called the *Anomalistic Year*, and is 365 days 6 hours 13 minutes 48 seconds in length.

Besides travelling round the sun once in a year, our globe has also a movement, or rotation, round its axis once every 23 hours 56 minutes 4 seconds. This period is termed a *Sidereal Day*, because in exactly this interval the stars, which are apparently fixed on the celestial sphere, return to the same positions with respect to the horizon of the observer. As the earth, however, is not at rest, but rapidly revolving round the great centre of the planetary system, the sun is apparently caused to move among the stars in an easterly direction, and is thus on the average about four minutes longer than a sidereal day in returning to the meridian. The mean *Solar Day* is accordingly 24 hours in length, while the actual or apparent day alters slightly throughout the year. This is owing to the varying speed of our globe in her orbit, which lengthens or shortens the observed interval between the successive returns of the sun to the meridian, or the true solar day.

The axis round which the earth performs her rotation is greatly inclined to the plane of the path in which she moves. At present it is inclined at an angle of 23 degrees 27 minutes from a vertical to the plane of the ecliptic, and this is also the angle between the terrestrial equator and the ecliptic. Like the eccentricity of the orbit, this inclination, which is called the obliquity of the ecliptic, is subject to a slight alteration. During the last two thousand years it has decreased to the extent of about twenty-four minutes, and is still decreasing at the rate of about half a second of arc each year. It is computed that the diminution will continue for about fifteen thousand years, when the obliquity will be reduced to about 22¼ degrees. The direction of movement will then change, and the axis of our globe will begin to recede from a vertical to the orbit, or from the poles of the ecliptic, and the obliquity will accordingly increase. It is believed, however, that the whole variation can never exceed two and a half degrees, so that the seasons, which entirely depend on the inclination of the axis, can never seriously be altered.

THE OBSERVED OBLIQUITY OF THE ECLIPTIC FOR NEARLY 3000 YEARS.

DATE.	*OBSERVER.*	*OBLIQUITY, OR INCLINATION OF THE EQUATOR TO THE ECLIPTIC.*	*DATE.*	*OBSERVER.*	*OBLIQUITY, OR INCLINATION OF THE EQUATOR TO THE ECLIPTIC.*
1100 B.C.	Tchcon-Kong (China).	23° 54′ 2″	1690 A.D.	Flamsteed at Greenwich.	23° 28′ 48″
350 ,,	Pytheas at Marseilles.	23° 49′ 20″	1750 ,,	Lacialle.	23° 28′ 19″
200 ,,	Eratosthenes.	23° 51′ 15″	1755 ,,	Bradley at Greenwich.	23° 28′ 15″
140 ,,	Hipparchus.	23° 51′ 20″	1769 ,,	Maskelyne.	23° 28′ 10″
827 A.D.	Arabians at Baghdad.	23° 33′ 52″	1800 ,,	Do.	23° 27′ 57″
890 ,,	Albategni at Antioch.	23° 35′ 41″	1815 ,,	Bessel.	23° 27′ 47″
1150 ,,	Almansor.	23° 33′ 30″	1825 ,,	Pearson.	23° 27′ 44″
1278 ,,	The Chinese.	23° 32′ 12″	1841 ,,	Bouvard at Paris.	23° 27′ 35″
1430 ,,	Ulugh Begh (Samarkand).	23° 31′ 58″	1868 ,,	Airy at Greenwich.	23° 27′ 22″
1590 ,,	Tycho Brahé.	23° 29′ 52″	1890 ,,	(Nautical Almanac).	23° 27′ 13″
1672 ,,	Cassini at Bologna.	23° 29′ 15″			

MARS.

"Each sun with the worlds that round it roll,
Each planet poised on her turning pole,
With her isles of green, and her clouds of white,
And her waters that lie like fluid light."—*Bryant.*

WE now come to the outermost member of the inner group of orbs—the planet MARS—the least of all the major planets, with the exception of MERCURY. MARS revolves round the sun at an average distance of 141½ millions of miles, in a path very elliptical in shape (*see Plate* 11). In fact, the eccentricity of his orbit is, after MERCURY'S, greater than in the case of any other large planet. It amounts to about one-eleventh (0·093) of the semi-major axis of the orbit. The distance of the planet is consequently subject to great variation. When nearest to the sun, the distance amounts to nearly 128 millions of miles, and when at his farthest from the centre of the system, to over 155 millions of miles. The time occupied by the planet in making a circuit of this orbit is nearly twice greater than in the case of our earth. More exactly, it is equal to 1 year 10½ months; this gives an average orbital velocity of about 15 miles per second.

From being situated immediately outside the terrestrial orbit, the distance of the planet from the earth varies to an enormous extent. When in opposition to the sun, for example, or when seen near the meridian at midnight, MARS is then nearer to our globe than when in the opposite part of the heavens, or in conjunction with the sun, by a whole diameter of the martial orbit, *minus* the difference between the distances of the planet and the earth from the sun, or by no less than 234 millions of miles.* The distance between the two planets, when MARS is in opposition to the sun, or when they are in conjunction with each other, amounts to nearly 49 millions of miles. This is the *average* distance, however, for the planet is sometimes nearer, and occasionally further away than this when in opposition. As already mentioned, the distance of the planet from the sun varies to the extent of about 26 millions of miles, which is also the amount by which the opposition distances alter. If the planet, accordingly, happens to be near the aphelion of its orbit, or at its greatest distance from the sun, when in conjunction with our globe, the least distance between the two planets is then greatest, and amounts to 61 millions of miles. If, on the other hand, the opposition occurs when the planet is in perihelion, the distance is then the shortest possible, being only 35 millions of miles. As might be expected, this great variation of the planet's distance when in opposition produces a considerable alteration in its brilliancy, and in the apparent size of its diameter. But this variation of brightness is even more marked than it would be solely from an increase or decrease of distance between the two bodies. When MARS is nearest to the earth, he is then nearest to the sun, and, therefore, his disc is more brilliantly illuminated than when situated at his mean distance. Accordingly, the difference between the brilliancy of the planet when nearest to us at opposition, and when farthest away, is as great as five to one—*i.e.*, MARS, when seen in perihelion opposition, is five times brighter than when seen in aphelion opposition.

In size or volume the globe of the planet is about one-seventh of the volume of the terrestrial globe, its diameter being 4200 miles. The surface, therefore, amounts to about 55 millions of square miles, or is about equal to one-fourth of the earth's surface. The material of which the planet is formed is considerably lighter than the terrestrial material, its average density being only about seven-tenths of the density of the matter composing our globe; for, instead of being one-seventh of the mass of the earth, it is scarcely one-ninth of the terrestrial mass. The attraction of superficial gravity on the planet, or the force with which all objects are drawn towards the centre of the martial sphere, is also much less than on our globe. In fact, it is only about one-third of the attraction on the surface of the earth, or as 38 to 100; so that a body which weighs 100 pounds here, would, if removed to MARS, weigh only 38 pounds.

---

* =283,000,000 (the mean diameter of the orbit) – 48,700,000 (the difference between the distance of MARS and the earth), =234,300,000 miles.

Like the other members of the planetary system, MARS turns on his axis, making a complete rotation in 24 hours 37 minutes 22·7 seconds. This rotation period is known more accurately than that of any other planet, as it has been determined by observations of permanent markings on his surface, extending over two hundred years. The axis of rotation is, in the same manner as the axis of our globe, inclined slightly from a vertical to the plane in which the planet moves. This angle of inclination from the vertical, or between the planet's equator and the plane of its path, amounts to 24 degrees 50 minutes, which, it will be noticed, differs but slightly from the obliquity of the ecliptic. Accordingly, the Martial seasons which depend on this circumstance are much the same as our own, only they are of about twice the length, as each season on MARS lasts nearly five and a-half months.

To the telescopist MARS is the most interesting of the planets, as in appearance he approaches nearer to the earth than any other member of the planetary system. When viewed with a powerful instrument, the planet's disc is found to be covered with numerous delicately-tinted markings. These are of two distinct shades. The darker tints have a decidedly greenish hue, and the brighter parts a yellowish-red colour. The nature of these markings has long been known. The greenish portions of the disc are found to be large tracts of water, or oceans; and the ruddy parts land, or continents. This configuration of land and water on the surface of the planet has, from numerous observations of MARS made with the most powerful instruments on all parts of the earth, been very accurately delineated; and even a chart of the whole surface has been constructed. Such a chart, constructed from the most recent observations, is given in Plate 12. From this map it will be noticed that, as in the case of our earth, the southern hemisphere of the planet contains more water than the northern hemisphere. The winters there also appear to be more severe than in the opposite hemisphere, as the southern pole is covered with ice and snow to a wider extent than the northern pole. This difference of climate between the two hemispheres is believed to be chiefly owing to the present position of the planet's axis, a position which gives the winter to the southern hemisphere, at the time the planet is farthest from the sun. The ice-caps surrounding the poles of MARS are very conspicuous objects, and were among the first markings discovered on the surface of the planet (*see Plate* 15). Before the spectroscope was invented, it was almost impossible to know exactly of what the brilliant white markings near the poles were composed. Telescopic observation alone, however, did much to reveal their true nature. Careful scrutiny soon found that the polar cap, which, from the motion of the planet in its orbit, was being more and more directed to the sun, gradually diminished, while on the other hand the cap surrounding the opposite pole slowly increased as a consequence of the presence and withdrawal, from the alteration of the seasons, of the solar rays on the masses of polar snow and ice.

Within the last forty years several portions of the oceans of the planet have been found to have altered slightly in shape. In some instances it has been observed that hundreds of square miles of land have become covered with water, and as large portions of the seas have become dry. Most probably these changes have been produced by inundation, and also by an alteration of the surface level of parts of the planet's globe. This would be accomplished all the easier as the land in those parts where the changes have been detected is exceedingly flat and of about the same level as the surface of the water. In fact, nearly all the martial continents lie at rather a low level; as MARS is a planet not nearly so mountainous as MERCURY or our earth. Like the other members of the planetary system, MARS is surrounded with an atmosphere, and as there is water on his surface, evaporation will raise quantities of it, and clouds will be formed as on our globe. Indeed, clouds have not unfrequently been observed floating in the martial atmosphere, so that on MARS there undoubtedly takes place all the phenomena of rain, hail, and snow.

MARS, like VENUS, may not improbably be the abode of some form of life. If life, however, exists there, it will of necessity be greatly different from the varied forms we see on earth; as the conditions for the existence of life on a planet depend entirely on the planet's position, volume, density, and physical constitution. MARS, we have found, is more distant from the sun than the earth, consequently his supply of light and heat is considerably less than the terrestrial supply, being, indeed, scarcely one-half of the amount which the earth receives. This fact, however, cannot be taken as an exact index of the temperature of the martial surface. The temperature of a planet's surface certainly depends in a great measure on the distance of the planet from the sun, but it is considerably modified by the presence of an atmosphere. MARS, we know, has an atmosphere surrounding him, and an atmosphere, too, containing large quantities of watery vapour, which greatly increases its heat-retaining power, so that MARS is probably not so cold a planet as many have supposed. The mildness of the martial climates is also proved from the fact that the water on the surface of the planet is frozen only near the poles, and even there the cold is not so great as in our arctic and antarctic regions. The planet's snow-caps are also not nearly so extensive as those of our earth. But even though it were proved that the conditions of the surface of the planet were such that no *terrestrial* life could exist there, this does not by any means imply that there is no martial life whatever. We must not for a moment imagine that the forms of life found on our globe are the only possible ones; that, in short, the different orbs of the universe are exact representations of our sun, and the planets revolving round those orbs, and round our sun, are true copies of our globe. Modern scientific discovery has for ever dispelled such an absurd supposition. Accordingly there is some reason for believing that MARS may be the abode of intelligent life, or if not at present, may have been in the past an inhabited world.

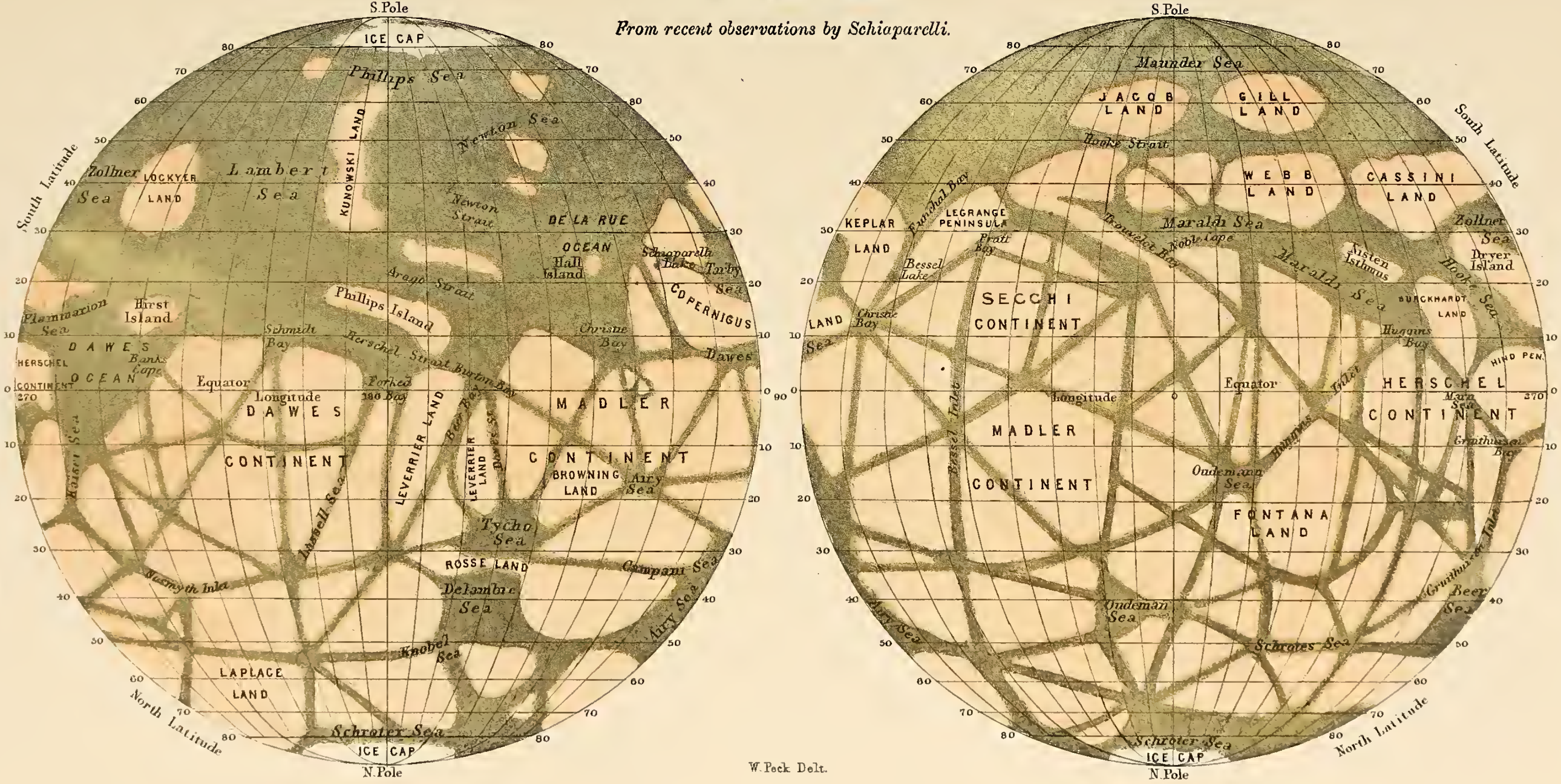
Till the year 1877 it was believed that MARS, like VENUS and MERCURY, had no satellite. Times without number the planet was examined with the most powerful telescopes, but all observers failed in turn. In the month of August, 1877, however, Professor Hall at Washington, with a new refracting telescope of twenty-six inches aperture, discovered that the planet had two moons revolving round him. They are exceedingly minute globes, thought to be less than ten miles in diameter, and can only be seen with the largest instruments, and only with these when MARS is nearest to the earth at the time of opposition. The outer one, DEMOIS, is situated from the centre of the planet at a distance of 14,600 miles (*see Plate* 14). Its period of revolution is exceedingly short, being only 30 *hours* 18 minutes in length; in which time it will undergo all its phases. PHOBOS, the inner satellite, is distant 5,800 miles from the centre of MARS, and 3,700 miles from his surface. Unlike any other satellite in the solar system, the time occupied by it in making a complete revolution of its orbit is considerably shorter than the period of the planet's rotation. The revolution is completed, in fact, in less than one-third of the martial day, or in 7 hours 39 minutes. From these rapid revolutions of the satellites, there results the most striking pecularity. PHOBOS, the inner one, for instance, will appear to rise in the western part of the sky and set in the east, notwithstanding the fact that its direction of revolution is the same as in the case of our own moon, or from west to east. The interval between rising and setting, however, will be lengthened from the planet's rotation, and in consequence a complete change of phases will be accomplished while above the horizon. As seen from the surface of MARS the apparent movement of the outer satellite will be just as peculiar. Its period of revolution, we have seen, coincides more closely with the rotation period of the planet, than that of the inner moon, and consequently its apparent movement in the sky, or with respect to the horizon, will be exceedingly slow, while its sidereal movement, or its motion among the stars, will be as rapid as the angular movement in its orbit. Like our own moon, DEMOIS will rise in the east and set in the west, but from the slowness of its apparent movement in the sky, the interval between rising and setting will be lengthened to no less than 132 hours, in which time four complete changes of phases, or four orbital revolutions, will actually be accomplished.

CHART OF MARS—PLATE 12.

CHART OF THE PLANET MARS,

IN TWO HEMISPHERES.

From recent observations by Schiaparelli.


S.Pole
ICE CAP
Phillips Sea
KUNOWSKI LAND
Newton Sea
Zollner Sea
LOCKYER LAND
Lambert Sea
Newton Strait
DE LA RUE OCEAN
Hall Island
Schiaparelli Lake
Terby Sea
COPERNICUS
Arago Strait
Phillips Island
Hirst Island
Flammarion Sea
DAWES OCEAN
Banks Cape
HERSCHEL CONTINENT
Schmidt Bay
Herschel Strait
Burton Bay
Christie Bay
Dawes
Equator
Longitude
DAWES CONTINENT
Forked 180 Bay
LEVERRIER LAND
Beer Bay
Dawes Sea
MADLER CONTINENT
BROWNING LAND
Airy Sea
Kaiser Sea
Lassell Sea
Tycho Sea
ROSSE LAND
Nasmyth Inlet
Delambre Sea
Campani Sea
Airy Sea
Knobel Sea
LAPLACE LAND
Schroter Sea
ICE CAP
N.Pole
South Latitude
North Latitude
Maunder Sea
JACOB LAND
GILL LAND
Dawes Strait
WEBB LAND
CASSINI LAND
KEPLAR LAND
Funchal Bay
LEGRANGE PENINSULA
Pratt Bay
Bessel Lake
Brouwelia Bay
Noble Cape
Maraldi Sea
Zollner Sea
Dryer Island
Aisten Isthmus
Hooke Sea
BURCKHARDT LAND
Huggins Bay
SECCHI CONTINENT
LAND
Christie Bay
Sea
HIND PEN.
HERSCHEL CONTINENT
Main Sea
Gruithuisen Bay
Huggins Inlet
Bessel Inlet
MADLER CONTINENT
Oudemann Sea
FONTANA LAND
Gruithuisen Inlet
Beer Sea
Airy Sea
Oudeman Sea
Schroter Sea
Schroter Sea
ICE CAP
N.Pole
South Latitude
North Latitude
0
10
20
30
40
50
60
70
80
90
270

W. Peck Delt.

Gill & Inglis, Edinburgh.

THE ASTEROIDS.

Towards the end of last century, and before Neptune had been discovered, it was thought that the different planets were, according to some definite law, placed at certain distances from the sun. It was known, for instance, that if the various orbs from Mercury to Uranus were represented by the geometrical series, 0, 3, 6, 12, 24, &c., and each number of the series further increased by 4 (as in the following Table), the numbers thus obtained approximately represented the distances of the different planets from the sun. But while this was found to be the case it was noticed that before this regularity of arrangement of distance could be considered as complete, a planet ought to revolve in a place where hitherto no planet was known to exist—viz., between the orbits of Mars and Jupiter. Astronomers, accordingly, began the search for the supposed orb, which, if it existed, could not be a very large one, or it would have already been discovered. Their labours were soon rewarded, for on the very first day of the present century, Piazzi, at Palermo, discovered the small planet Ceres, which, curiously enough, was found to be revolving exactly at the distance which had been assigned to it. But this was not all. Two years after this remarkable discovery, on the 28th of March, 1802, another small planet, which was called Pallas, was discovered by Olbers at Bremen. These discoveries were soon followed by two others—viz., the small planet Juno, on the 1st of September, 1804, and Vesta, on 29th March, 1807. No additional asteroid, however, was discovered for thirty-eight years, but since the year 1845, there has scarcely been a year without their number being greatly increased, till at present nearly three hundred of these small planets have been discovered. These, however, do not represent their actual numbers, which very probably can only be reckoned by millions.

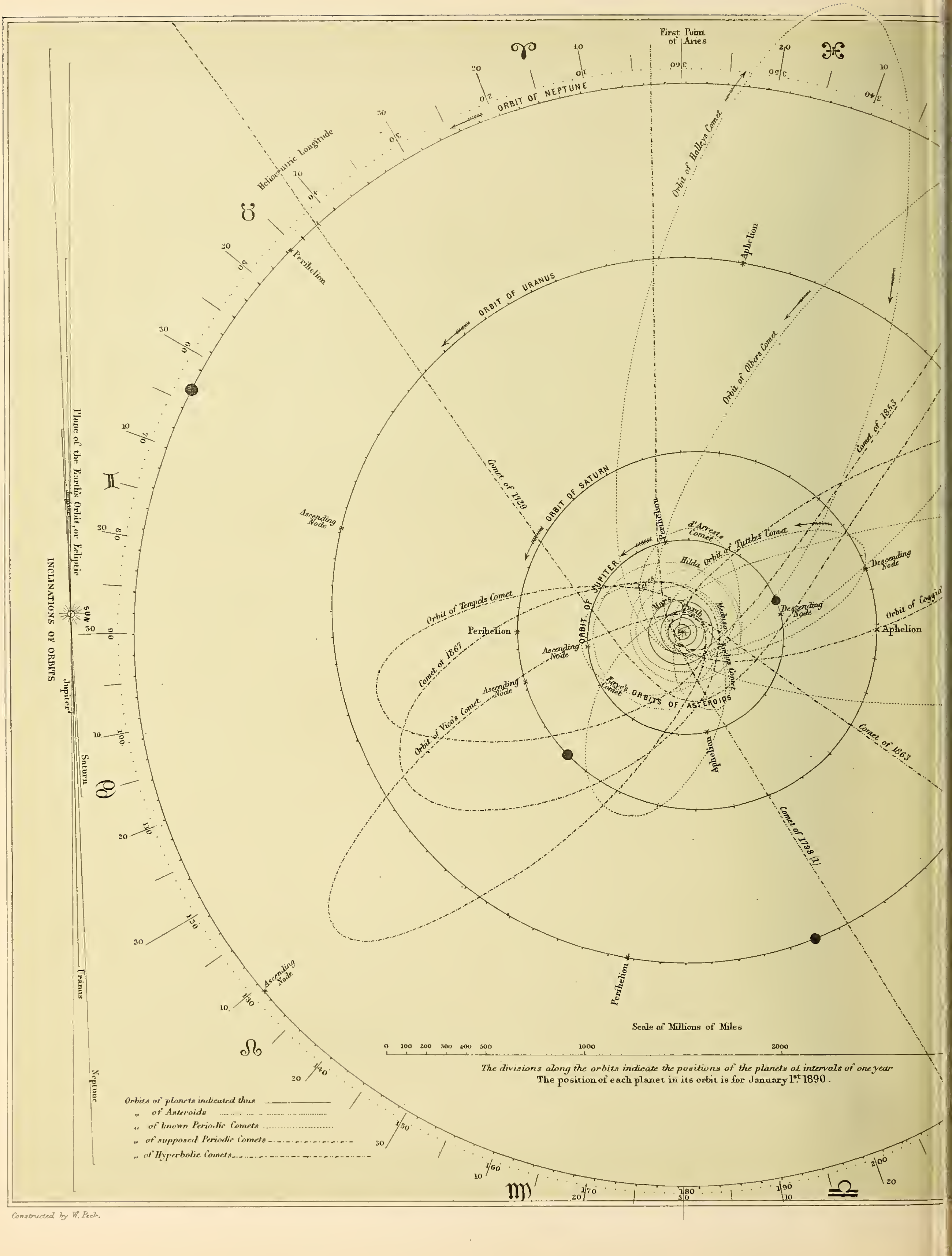
PLANETS.	Mercury.	Venus.	The Earth.	Mars.	Missing Planet.	Jupiter.	Saturn.	Uranus.
Geometrical Series	0	3	6	12	24	48	96	192
+ 4	4	4	4	4	4	4	4	4
Resulting Distances	4	7	10	16	28	52	100	196
Actual Distances	3·9	7·2	10	15·2	...	52	95·4	191·8

The paths in which these tiny orbs revolve are situated at different distances from the sun, and at various inclinations to the plane of the ecliptic (*see Plate* 13). The one known as Medusa (149) has the least mean distance, or 198 millions of miles, and has consequently the shortest period of revolution—viz., 3 years 40 days. Hilda (153) on the other hand, is the most distant member of the group as at present known. Its average distance from the sun is 366 millions of miles, and its period of revolution is accordingly nearly eight years. The asteroids thus form a ring of tiny orbs, revolving between the paths of Mars and Jupiter, whose breadth is no less than 168 millions of miles, or nearly equal to the diameter of the terrestrial orbit. The paths of these small orbs do not, in general, deviate far from the ecliptic plane, being on the average inclined to the plane of the earth's orbit at an angle of about six degrees. Several, however, have orbits inclined at an angle considerably greater than this. The orbit of Pallas, for instance, has an inclination of no less than thirty-five degrees (*see Plate* 13).

In size the asteroids may be considered as the smallest bodies of the planetary system. The largest even

(VESTA) is believed to have a diameter of only three hundred miles. The remaining three of the four first discovered have probably diameters no greater than two hundred miles; while many of the others cannot have diameters larger than fifty miles, the vast majority of them being globes, in all likelihood, as small as ten or twenty miles in diameter. With regard to their mass very little is known, but from the irregularities of the movements of MARS it has been calculated that the *combined* masses of *all* the asteroids cannot be greater than one-fourth of the mass of our globe, and would, if put together, only form a sphere with a diameter of about 5000 miles. This clearly proves that even the largest asteroid can neither be a very large nor heavy globe. Most probably it would be only one twenty-thousandth of the weight of the earth; while the smallest may be no heavier than one of those huge projectiles, which are occasionally fired from the largest pieces of ordnance.

The origin of these asteriods is probably the outcome of the condensation of a mighty ring of nebulous material, which, instead of breaking up and forming large globes, as in the case of the other planets, condensed into numerous smaller ones. This would doubtless be owing to the attractions of the large planet revolving immediately outside their paths—viz., JUPITER, the giant of the system. Their production, certainly, cannot be accidental, as some have supposed, but the outcome of a definite law. The peculiar position they occupy in the system very well proves this, for they divide the larger planets into two important groups—the inner members from the outer—the terrestrial planets from the giant planets.

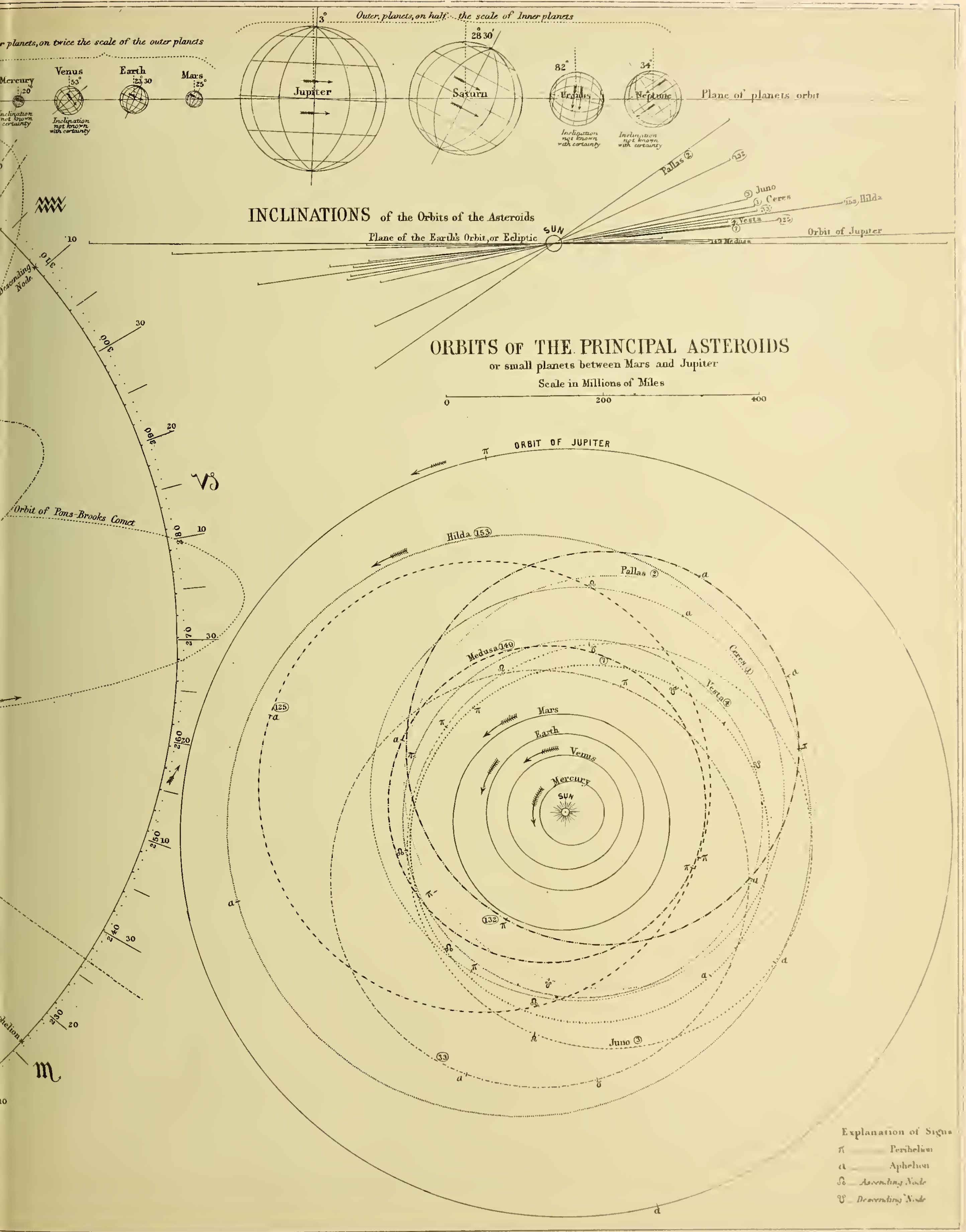

First Point of Aries
ORBIT OF NEPTUNE
ORBIT OF URANUS
ORBIT OF SATURN
ORBIT OF JUPITER
ORBITS OF ASTEROIDS
Heliocentric Longitude
Orbit of Halley's Comet
Orbit of Olbers Comet
Comet of 1853
Comet of 1729
Comet of 1863
Comet of 1867
Comet of 1798 (I)
Orbit of Tempels Comet
Orbit of Vico's Comet
Orbit of Tuttles Comet
Orbit of Coggia
d'Arrests Comet
Encke's Comet
Fayes Comet
Hilda
Medusa
Mars
Earth
Perihelion
Aphelion
Ascending Node
Descending Node
Plane of the Earth's Orbit, or Ecliptic
INCLINATIONS OF ORBITS
SUN
Jupiter
Saturn
Uranus
Neptune
Scale of Millions of Miles
0
100
200
300
400
500
1000
2000

The divisions along the orbits indicate the positions of the planets at intervals of one year.
The position of each planet in its orbit is for January 1st 1890.

Orbits of planets indicated thus
" of Asteroids
" of known Periodic Comets
" of supposed Periodic Comets
" of Hyperbolic Comets

Constructed by W. Peck.

THE SOLAR SYSTEM—PLATE 13.



INCLINATIONS of the Orbits of the Asteroids

ORBITS OF THE PRINCIPAL ASTEROIDS

or small planets between Mars and Jupiter

Scale in Millions of Miles

r planets, on twice the scale of the outer planets
Outer planets, on half the scale of Inner planets
Mercury
20°
Inclination not known with certainty
Venus
53°
Inclination not known with certainty
Earth
23°30
Mars
25°
Jupiter
3°
Saturn
28°30′
Uranus
82°
Inclination not known with certainty
Neptune
34°
Inclination not known with certainty
Plane of planets orbit
Pallas ②
Juno
Ceres
Hilda
Vesta
Orbit of Jupiter
Medusa
SUN
Plane of the Earth's Orbit, or Ecliptic
0
200
400
ORBIT OF JUPITER
Hilda (153)
Pallas ②
Ceres ①
Vesta ④
Medusa (149)
(125)
(132)
(33)
Juno ③
Mars
Earth
Venus
Mercury
SUN
Descending Node
Orbit of Pons-Brooks Comet
Perihelion
310
300
290
280
270
260
250
240
230
10
20
30

Explanation of Signs

π —— Perihelion

a —— Aphelion

☊ — Ascending Node

☋ — Descending Node

Engraved by [illegible] Edinʳ

JUPITER.

> "Flowers of the sky! ye, too, to age must yield,
> Frail as your silken sisters of the field."—*Erasmus Darwin.*

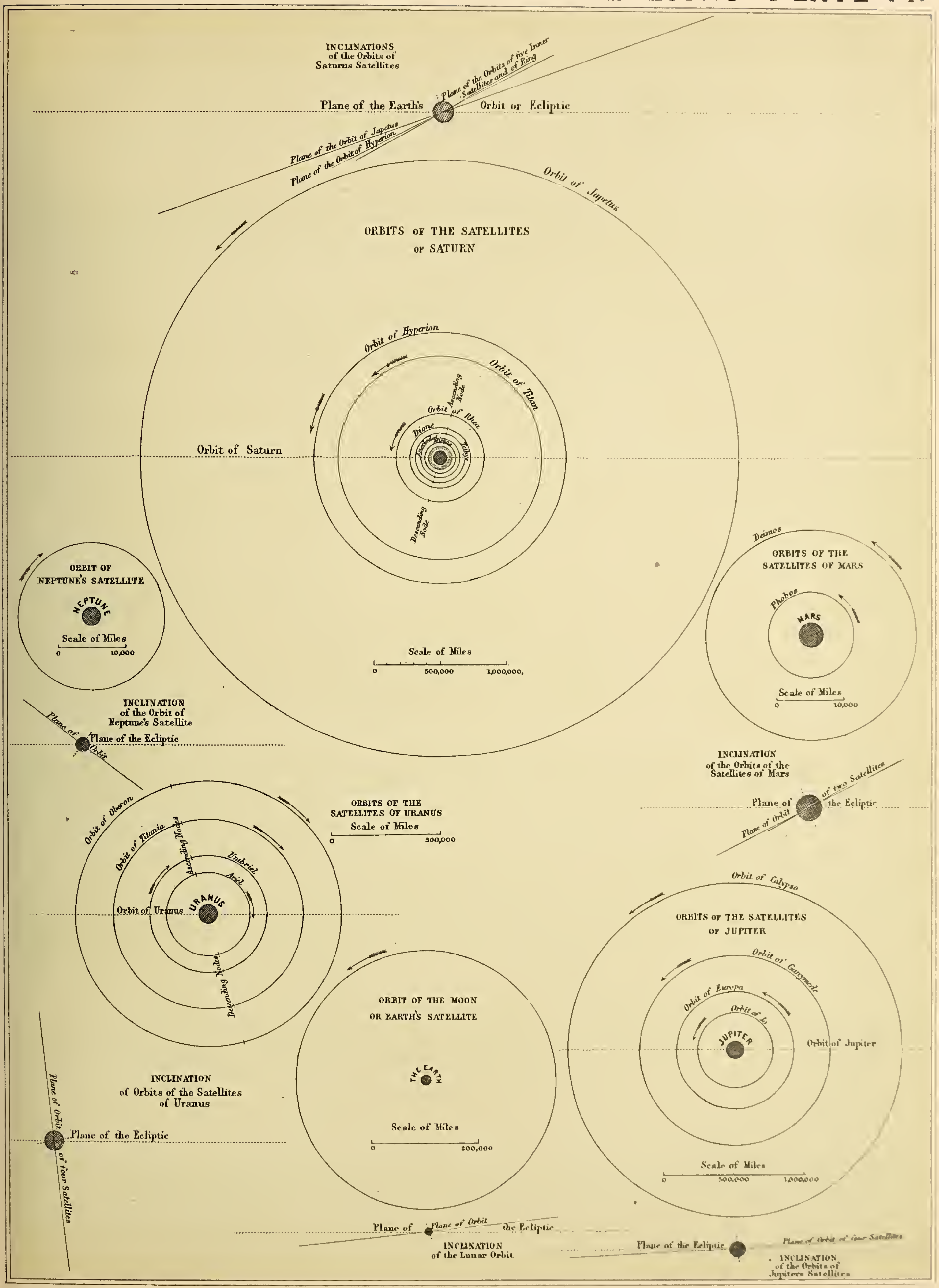
As already mentioned, this is the nearest member of the outer group of orbs, and the largest planet in the system. On the average, this giant planet is situated from the sun at a distance of 483 millions of miles. As the eccentricity of the orbit, however, amounts to about one-twentieth of the semi-major axis (0·048) his distance from the sun varies to the extent of about 42 millions of miles. In traversing this large orbit the planet journeys at the velocity of slightly over eight miles per second, and accordingly occupies nearly twelve years, or 4332·6 days, in making a complete revolution. In size and weight JUPITER far exceeds any other member of the planetary system, being, in fact, larger and heavier than all the other planets put together. The equatorial diameter of this large globe is no less than 88,200 miles—thus exceeding the diameter of the earth, as much as the diameter of the sun exceeds that of JUPITER itself. The shape of this huge planet is very elliptical, and his ellipticity is such as to be clearly perceptible when viewed with the telescope. Owing to this ellipticity the polar diameter is about one-seventeenth, or actually 5000 miles less than the equatorial diameter, and is therefore equal to 83,000 miles. From this large diameter it follows that the surface of the planet is 119 times, and the volume 1300 times larger than those of the earth. But though JUPITER is so many times larger than our globe, he is only about 316 times heavier, which proves that the matter composing the globe of the planet must be considerably lighter than that which forms our earth. In fact, this gigantic planet is but little heavier than if he were composed entirely of water—his density being scarcely one-fourth of the earth's, and exactly the same as that of the sun. The amount, however, of this very light material is so great that, notwithstanding the distance of his visible surface from his centre, the attraction of gravity there will be nearly three times greater than it is on the surface of our globe. This, however, is taking the visible surface as representing the real surface of the planet. In all probability the actual surface is considerably smaller, for the planet is surrounded with an exceedingly dense atmosphere, which is certainly several thousands of miles in depth. Therefore, on the true surface of JUPITER'S globe, the attraction will be very much greater than what we have been considering as the amount on the visible surface.

When examined with a telescope, the disc of JUPITER is seen to be crossed with several delicately-coloured bands, and it is from observations of these bands that the rotation period has been determined. This period, notwithstanding the gigantic size of the planet, is very short, being only about 9 hours 55 minutes. Sometimes the belts, as the coloured bands are called, are of a pale bluish colour, while occasionally portions of them have a red appearance. These markings are entirely atmospheric, being simply large cloud masses, which are continually shifting in position, and altering in shape, even while they are being viewed (*see Plate* 15). They are arranged in strips parallel to the planet's equator, doubtless resulting from his rapid rotation, which will produce winds blowing constantly in one direction, or similar to our trade winds on earth. These winds, too, must occasionally blow with more than hurricane force, judging from the rapidity with which the cloud-zones sometimes change their form. Indeed, clouds in the atmosphere of JUPITER have actually been observed to travel over a distance of two hundred miles in so short an interval as an hour. This shows that the surface of the planet must be subjected to atmospheric storms more tremendous than are ever experienced on earth. These Jovian hurricanes that are continually raging owe their existence to the planet's internal heat; for, thousands of miles below the visible surface, there is situated the red-hot fiery nucleus, part of which is occasionally seen whenever a portion of one of the great cloud-zones is for a time dispersed.

It would seem, then, that at present this gigantic planet cannot be the abode of life. For, independent of the internal heat, the storms on his surface are such that no forms of life known to us could ever survive their effect. It is rather a planet in preparation for life, in a condition similar to that in which our earth was many millions of years ago, when no life whatever could have existed on her surface—at a time, in our world's history, so very remote that geology can only infer its existence. This reveals the enormous length of the periods of time that are required for a planet to condense and cool from the molten state, and become fit for the abode of living creatures; and it also reveals that the entire duration of life on a planet is infinitely short in comparison with the planet's existence.

JUPITER has no less than four satellites, which were the first heavenly bodies discovered with the telescope. They revolve round him at distances ranging from 262,000 to over one million of miles, and in periods varying from 1 day 18½ hours to 16 days 16½ hours (*see Plate* 14, *also Table at end of chapter*). The paths in which they move are nearly circular in shape, and coincide with the plane of the planet's equator. The largest of these moons, GANYMEDE, has a diameter approaching MERCURY'S, or about one-half that of the earth, being no less than 3600 miles. The diameter of the next largest is 3000 miles, while the other two are globes of about the same size as our own moon, with diameters of slightly over 2000 miles. Though they are so large, they are formed of very light material, lighter even than that composing the globe of JUPITER, for they are each about the same weight as if formed of cork. Owing to their orbits being situated nearly in the plane of JUPITER'S orbit, which does not differ greatly from the plane of his equator, the satellites, with the exception of the most distant one, pass through JUPITER'S shadow, and are eclipsed at every revolution; and it was from observations of these eclipses that the Danish astronomer Roemer, in the year 1675, discovered that light occupied time in journeying over a given distance. More modern observations show that the eclipses of all the satellites take place 16 minutes later, when the planet is in conjunction with the sun, or when furthest from the earth, than when in opposition, or nearest to our globe, which is the time occupied by light in travelling from one side to the other of the terrestrial orbit.

THE ORBITS OF THE SATELLITES—PLATE 14.


INCLINATIONS of the Orbits of Saturns Satellites
Plane of the Earth's
Orbit or Ecliptic
Plane of the Orbits of five Inner Satellites and of Ring
Plane of the Orbit of Japetus
Plane of the Orbit of Hyperion
Orbit of Japetus
ORBITS OF THE SATELLITES OF SATURN
Orbit of Hyperion
Orbit of Titan
Ascending Node
Orbit of Rhea
Dione
Enceladus
Mimas
Tethys
Orbit of Saturn
Descending Node
Scale of Miles
0
500,000
1,000,000,
ORBIT OF NEPTUNE'S SATELLITE
NEPTUNE
Scale of Miles
0
10,000
INCLINATION of the Orbit of Neptune's Satellite
Plane of Orbit
Plane of the Ecliptic
Deimos
ORBITS OF THE SATELLITES OF MARS
Phobos
MARS
Scale of Miles
0
10,000
INCLINATION of the Orbits of the Satellites of Mars
Plane of
Plane of Orbit
of two Satellites
the Ecliptic
Orbit of Oberon
Orbit of Titania
Ascending Nodes
Umbriel
Ariel
URANUS
Orbit of Uranus
Descending Nodes
ORBITS OF THE SATELLITES OF URANUS
Scale of Miles
0
500,000
INCLINATION of Orbits of the Satellites of Uranus
Plane of Orbit of four Satellites
Plane of the Ecliptic
ORBIT OF THE MOON OR EARTH'S SATELLITE
THE EARTH
Scale of Miles
0
200,000
Plane of
Plane of Orbit
the Ecliptic
INCLINATION of the Lunar Orbit
Orbit of Calypso
ORBITS OF THE SATELLITES OF JUPITER
Orbit of Ganymede
Orbit of Europa
Orbit of Io
JUPITER
Orbit of Jupiter
Scale of Miles
0
500,000
1,000,000
Plane of the Ecliptic
Plane of Orbit of four Satellites
INCLINATION of the Orbits of Jupiters Satellites

Engraved by Archibald & Peck Edin.r

[illegible]

SATURN.

"In the deep stillness of the night,
When weary labour is at rest,
How lovely is the scene!"—*Miller.*

To those who are familiar with the more important of the star groups, the movements of this planet round the heavens will be watched with special interest. For many centuries, the movements of this and similar orbs have constantly been observed. In fact, thousands of years before our era, the shepherd astronomers in the extensive plains of Chaldea or Central Asia had—

"Watched, from the centres of their sleeping flocks,
Those radiant Mercuries that seemed to move,"

and discovered that while nearly all the starry host seemed stationary with regard to each other, though appearing, of course, to turn daily round the sky, yet at least four orbs were constantly changing their positions. By these early astronomers the movements of the wandering stars were carefully watched, and their tracks among the constellations recorded. By this means it was found that these orbs did not all move with the same velocity. Some appeared to travel very rapidly, while others were observed to move with great slowness. The fastest moving orb, which we now call VENUS, was the most brilliant; the slowest moving one, SATURN, the least conspicuous. From his sluggish movements and dull appearance, the alchemists of old likened him to the heavy and lustreless metal, lead; while the astrologer selected him as a fit orb for producing the most mischievous influences on the human race.

How vastly different all this is from the reality! "Truth," it has been well said, "is stranger than fiction." Modern science shows that the apparently insignificant is often the most wonderful, and, in doing this, it teaches us a valuable lesson—a lesson which we should not be slow to learn—viz., that we ought not to judge quickly as to the ways and works of the Creator; not to say that this and that is the manner in which a particular object has been created, but rather, with patience, to search constantly after those great and sublime truths about the universe which are being slowly unfolded around us every day. To no object can this caution apply more than to SATURN. That dull orb, which so sluggishly appears to drag its course from constellation to constellation, is actually rushing through space at a speed which is more than twenty times that of a cannon ball, or six miles per second, and makes a complete circuit of its mighty path round the sun in about 29½ years. The average distance of the planet from the sun is about 886 millions of miles, or nearly ten times greater than the distance of our earth. Yet this vast orbit—whose span thus amounts to 1800 millions of miles, over which light requires two hours and three-quarters to journey—is in turn insignificant when compared with the paths of the two large planets URANUS and NEPTUNE, which have been discovered to revolve far beyond.

Let us now turn that most useful instrument, the telescope, upon this apparently insignificant object. When this is done on some calm and clear evening, the picture presented to our eyes is magnificent. What, to the unaided eye, seems to be only an ordinary and not particularly brilliant star, appears under a high magnifying power, to be one of the most beautiful objects in the heavens—a glorious orb, whose shining surface is resplendent with the most delicately-coloured tints, and which is surrounded with a wonderful and complicated system of revolving rings (*see Plate* 15).

Of the eight large globes which form the sun's planetary family, SATURN is by far the most wonderful. Second only in size to the giant planet JUPITER, he is himself a gigantic orb. The diameter of his mighty globe is no less than 75,000 miles, or over nine times greater than the diameter of the earth. Like our globe, his true shape is not exactly spherical; the polar diameter is nearly 7000 miles shorter than a diameter passing through his equator. The diameter of the planet being so large, his volume is in consequence 740 times greater than the volume of the earth; or, in other words, it would require 700 globes, equal to ours in size, to form a globe the size of SATURN. This huge ball rotates in the same manner as our earth, but much more rapidly; for instead of taking twenty-four hours, as our earth does, to make a complete revolution, SATURN rotates on his axis in a little over ten hours. Owing to this rapid rotation, the equatorial regions of the planet are carried round at a tremendous velocity—a velocity nearly similar to that with which SATURN is carried round the sun—of about six miles per second.

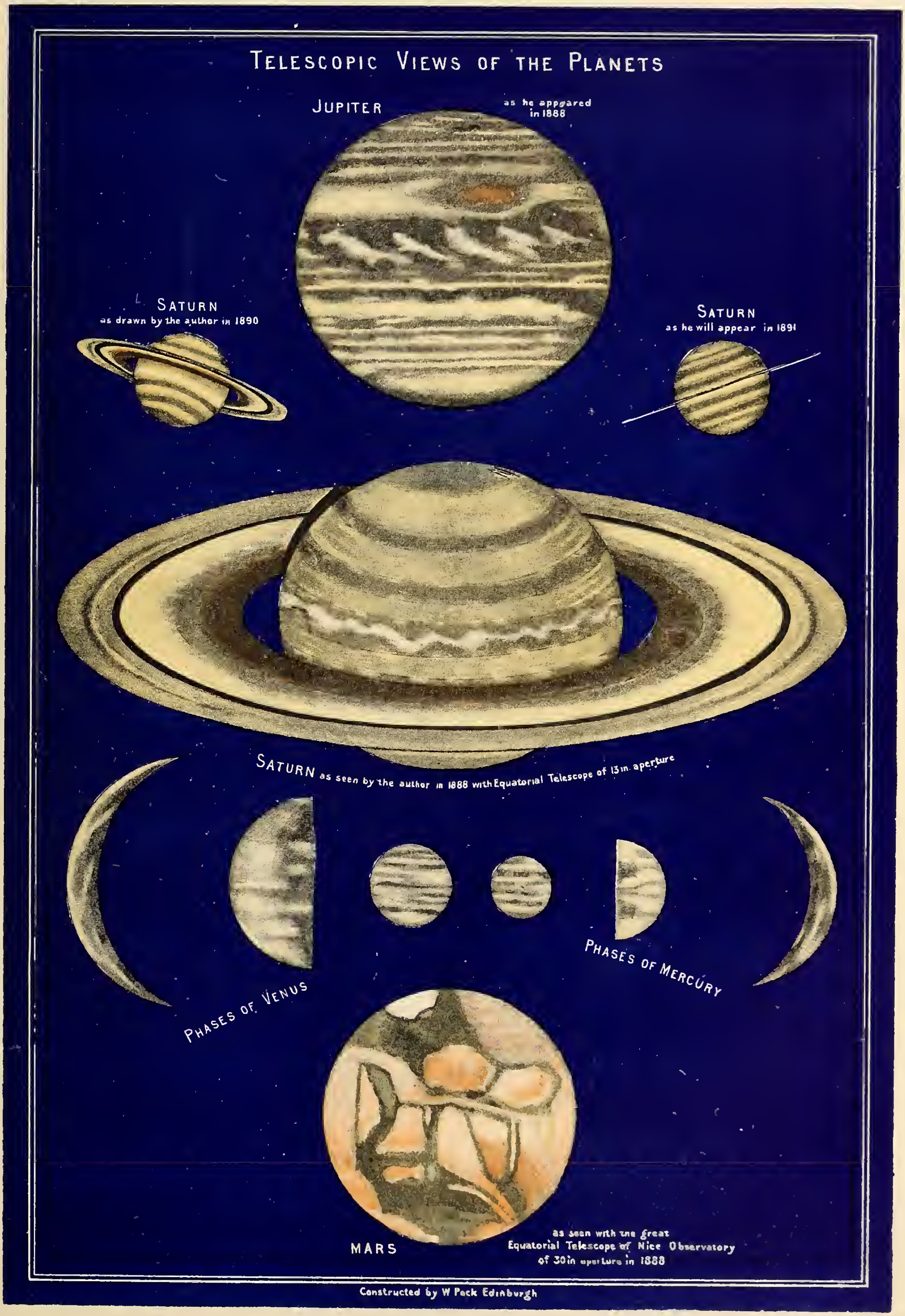
In mass, or the amount of matter which he contains, SATURN does not exceed our earth in the same proportion as he does in volume; his bulk being only about one hundred times greater than that of our globe. Accordingly, while it would take 700 globes, equal to ours in size, to form a globe as large as SATURN'S, it would only require ninety-five earths to form a globe equal to SATURN in weight. Now, as the planet is much larger, in proportion to its weight, than our earth, it follows that the materials of which he is built up, must be very much lighter than those forming our globe. In fact, the matter composing the gigantic globe of SATURN is so light, that if the planet could be placed in some mighty ocean, it would actually float with about one-fourth of its bulk above the surface of the water.

In all probability SATURN is composed of materials similar to those of our globe. How is it then that they are so light comparatively? The pressure on the central parts of the planet must be enormous—quite sufficient, indeed, to form matter of great density. Yet we find that the whole globe is so light that it would float in water! The cause of this is to be found in the fact that the planet is exceedingly hot. This prevents even the great pressure of the central parts from forming any solid material; so that at present the mass of the planet is simply expanded by heat. What we see in the telescope is not the real surface of SATURN, but his cloud-laden atmosphere; far below which, there exists his glowing central ball. By the planet's rapid rotation, as in the case of JUPITER, these cloud-layers are thrown into numerous concentric zones, or "belts" (*see Plate* 15), which, when the air is exceedingly clear, are seen to be beautifully coloured. The general surface of the planet has a yellow appearance. Near the poles the colour is somewhat blue, while the equatorial belts are of a bright cream-coloured tint, and often contain brown, red, and purple spots.

The most wonderful part of the planet, however, is his peculiar appendage. The breadth of this marvellous ring system is no less than twenty-one times greater than the diameter of the earth, yet it is so amazingly thin, that when placed exactly edgeways to us, it often disappears from view, and SATURN is then seen like any of the other planets—ringless. The bright ring, it will be noticed, is divided into two parts by a dark strip, called after its discoverer, "Cassini's division." This dark strip is nearly 2000 miles in breadth. Each of the two rings thus formed is in all probability broken up into numerous smaller rings. In 1856, it was discovered by means of one of the large American telescopes that within the large bright ring there is a dark and semi-transparent ring about 10,000 miles broad. This discovery was of the greatest importance, for it threw considerable light on the nature of the whole ring system. Before the telescope was powerful enough to reveal its complicated structure, and before mathematical analysis had demonstrated its nature, the ring was thought to be solid. The discovery of the "crape ring," however, showed that this was impossible, which confirmed the statements of mathematicians that no solid ring could exist, as the attractive power of the planet would have broken it in pieces. Neither, it was reasoned, could the rings be of the nature of a fluid. In fact, the wonderful system of rings with which SATURN is engirdled, is now known to consist of nothing more than multitudes of tiny orbs—small moons, or "pocket planets"—each revolving round SATURN in its own path, obeying as rigidly the great law of the universe, as our earth, or any of the larger members of the solar system.

Outside the rings, there revolve eight large satellites, or moons (*see Plate* 14). The smallest of these is thought to have a diameter about one-half that of our moon; while the largest is undoubtedly as large as the small planet MERCURY. As the outermost of these satellites journeys round SATURN at a distance of two and a-quarter millions of miles, the span of his entire system thus amounts to about four and a-half millions of miles

PLATE 15.


TELESCOPIC VIEWS OF THE PLANETS
JUPITER
as he appeared in 1888
SATURN
as drawn by the author in 1890
SATURN
as he will appear in 1891
SATURN as seen by the author in 1888 with Equatorial Telescope of 13 in. aperture
PHASES OF VENUS
PHASES OF MERCURY
MARS
as seen with the great Equatorial Telescope of Nice Observatory of 30 in aperture in 1888
Constructed by W Peck Edinburgh

—a breadth which is nearly twenty times greater than the distance which separates our moon from the earth.

At present, we have seen, Saturn is in a condition far too hot to be the abode of life. Yet though this is certainly the case, his heat may be of the greatest consequence to several of his satellites. At this enormous distance the heat of Saturn cannot, of course, be in the slightest degree sensible to us; yet for all that, it will be felt over his whole system—Saturn being to his moons as a subordinate sun, swaying them by his force, and supplying them with his heat. And in the future, long after the various forms of life on our globe shall have ceased to exist; when the water and atmosphere shall have been withdrawn into the interior; and when, in short, our earth shall have become like the moon at present—a desolate waste—Saturn will then have cooled down, and probably become a fit abode for living creatures. Saturn is thus a unique orb—an orb which shows us, that even among the various members of the sun's family of planets, there exists the most wonderful variety, as everywhere throughout the whole universe.

DIMENSIONS OF SATURN'S RINGS.

Diameter of Outer Ring, . .	173,000 miles.	Distance between Crape or Gauze Ring and Surface of the Planet, . .	9,000 miles.
Diameter of Cassini's Division, .	148,000 ,,	Breadth of Cassini's Division, . .	2,000 ,,
Diameter of Middle Ring, . .	112,000 ,,	Thickness of Ring, Probably less than	100 ,,
Diameter of Crape Ring, . .	91,000 ,,		
Width of Bright Rings, . .	30,500 ,,		

URANUS.

> "Each planet shining in his proper sphere,
> Doth with just speed his radiant voyage steer."—*Prior.*

THIS was the first planet discovered with the telescope, all the others interior to its orbit being visible to the unaided eye, and consequently known from very ancient times. The planet was first noticed to be a member of the solar system more than one hundred years ago—viz., on the 13th of March, 1781, though it had frequently been observed as a star on former occasions. On the evening of that day the elder Herschel, while examining the stars in the constellation of GEMINI, detected an object which did not appear as an ordinary star. In a short time, from careful watching, he found that the strange star was moving, and announced that he had discovered a comet. Repeated observations, however, soon proved that the new star could not be a comet, as it was travelling round the sun in an orbit nearly circular, but was, instead, a planet moving in a path at more than *twice* the distance of SATURN. Since its discovery URANUS has made more than a complete revolution of its orbit, having travelled from the constellation of GEMINI right round the zodiac, through GEMINI again to the constellation of VIRGO, where it is at present situated. Accordingly the period of the planet's orbital revolution is very accurately known, and from this its distance from the sun.* This period is slightly over eighty-four years, and consequently the distance from the sun will be over nineteen times greater than that of the earth, or about 1800 millions of miles, from which it follows that the planet moves in its path at a velocity of over four miles per second.

In size URANUS is slightly less than NEPTUNE, and is therefore the smallest member of the outer group of planets. The diameter of his globe amounts to about 32,000 miles, hence the surface is sixteen times, and the volume about sixty-six times, greater respectively than those of our earth. The density of the planet is very small, being about the same as that of JUPITER, and greater than the density of SATURN or NEPTUNE. The planet is thus but slightly heavier than if he were formed of water, and notwithstanding his gigantic size, his mass is only fifteen times greater than the mass of our globe. In shape, URANUS is not perfectly spherical, but like all the large planets, considerably compressed at the poles, the polar diameter being about one-fourteenth less than the equatorial diameter. It has recently been discovered that the planet's disc is crossed, like JUPITER'S and SATURN'S, by several faint bands, which implies that URANUS is, probably, in much the same condition as those giant orbs—a supposition which is borne out by the spectroscope, as the planet's spectrum is similar to those of JUPITER and SATURN.

URANUS has four satellites, which revolve round him in rather strangely situated paths (*see Plate* 14). In the case of the moons of JUPITER, and all the other satellites in the system, the paths in which they revolve are but slightly inclined to the plane of the ecliptic. The satellites of URANUS, however, move in a plane that is inclined at no less an angle than *eighty-two degrees* to the plane in which the planet itself journeys, and at this nearly perpendicular position to the planet's orbit, the moons revolve backwards, or from east to west.

---

* This is found from the "harmonic law," which is, that the squares of the periods of the planets are proportional to the cubes of their mean distances from the sun.

NEPTUNE.

> "Hence the view is profound,
> It floats between the world
> And the depths of the sky."—*Goethe.*

THIS is the most distant member of the sun's planetary family, as at present known. Its discovery was, unlike any other in the history of astronomy, made, not by aid of the telescope, but first from mathematical analysis; NEPTUNE being recognised as a planet revolving beyond the distant orbit of URANUS, before he had been detected with the telescope. Numerous observations had revealed that URANUS was not moving exactly in the path, and at the velocity assigned by calculation, even after every known perturbing element had been taken into account. This irregularity in its movement suggested to the French geometrician, M. Leverrier, and to the English mathematician, Mr. Adams, the existence of a planet revolving round the sun beyond its orbit. But these mathematicians went further. They not only suggested that such a planet existed, but from URANUS' movements they pointed out the exact part of the heavens where the planet would be seen. Direct the telescope to the constellation of AQUARIUS, wrote Leverrier, to longitude on the ecliptic 326 degrees, and a new planet will be found, in appearance like a star of the ninth magnitude. Accordingly the most powerful instruments were turned to that part of the sky, and at Berlin, on the evening of the 23rd of September, 1846, the planet was found, in a place distant from that indicated by calculation less than one degree, or scarcely two moon breadths.

According to calculation it was supposed that NEPTUNE revolved at a distance nearly twice that of URANUS, in accordance with the law stated on page 51. Observation, however, soon proved that this was not the case, that the so-called Bode's law, though approximately accurate for all the other planets, entirely failed in the case of NEPTUNE; and that, instead of revolving at double the distance of URANUS, the new planet made a complete circuit of its orbit in nearly double the *period* of URANUS' revolution. NEPTUNE, therefore, revolves round the sun at an average distance of about thirty times that of our earth, or over 2,800 millions of miles, and in a period of about 164 years, instead of 3,600 millions, and 217 years respectively, as it would have done if obeying Bode's law.

NEPTUNE is but slightly larger than URANUS, his diameter being about 35,500 miles, so that in volume he is ninety times greater than that of our earth. His mass is about eighteen times greater than the mass of our globe, which, combined with his great size, shows that like all the other members of the outer planets, he is composed of very light materials. In fact, his density is only about one-fifth of the density of terrestrial matter, or his globe is about as heavy as if it were formed entirely of water. Owing to the enormous distance at which this planet is situated, it is impossible to detect any markings on its surface, or to discover all its satellites. One moon, however, doubtless the largest, can be seen with any large telescope. It revolves round the planet in 5 days 21 hours, but in a direction *opposite* to that of the general movements of the various members of the system. The planets, we have mentioned, all revolve round the sun in one direction, from west to east. The satellites of the planets interior to the orbit of URANUS also move round their primary in this direction. The moons of URANUS, however, we have found, are an exception to this general rule, as they move in a plane nearly perpendicular to that in which the planet itself journeys, in a direction that, though certainly retrograde, may be regarded, from the perpendicular position of the orbits, as neither easterly nor westerly. NEPTUNE'S satellite travels in a direction that is entirely different; as the inclination of its path to the plane of the planetary orbits is not great, the direction of its revolution is distinctly retrograde, or from east to west (*see Plate* 14). This is also thought to be the direction in which the planet rotates on its axis, so that on NEPTUNE the heavenly bodies will probably appear to rise in the west and set in the east.

TRANS-NEPTUNIAN PLANET.

NEPTUNE is the most distant known planet in the system. Very probably, however, there is another planet, if not planets, revolving round the sun beyond his mighty orbit. From the movements of certain comets it is thought that the nearest of these far-off planets, if it exists, is situated at a distance, not of double that of NEPTUNE'S, but at about 4400 millions of miles, and will therefore, as in the case of NEPTUNE and URANUS, complete its orbital revolution in double the time occupied by NEPTUNE, or in about 330 years.

PRINCIPAL ELEMENTS OF THE PLANETARY SYSTEM FOR 1900.

	NAME OF PLANET.	SYMBOL.	MEAN DISTANCE FROM SUN.		ORBIT.				LIGHT AND HEAT.		
			Semi-major axis of orbit. Earth's distance as 1.	*In Millions of Miles.*	*Eccentricity of Orbit.*	*Inclination of Orbit to Ecliptic.*	*Longitude of Ascending Node.*	*Longitude of Perihelion.*	*At Perihelion.*	*At Aphelion.*	*Earth's, as 1.*
Inner Planets.	Mercury, .	☿	0·387	36·0	·2056	7° 0′ 8″	46° 24′ 40″	75° 11′ 50″	10·58	4·59	6·67
	Venus, .	♀	0·723	67·2	·0068	3° 23′ 35″	75° 1′ 59″	129° 26′ 38″	1·94	1·91	1·91
	The Earth,	♁ or ⊕	1·000	92·9	·0168	0° 0′ 0″	......	100° 31′ 2″	1·03	0·967	1·00
	Mars, .	♂	1·524	141·5	·0933	1° 51′ 2″	47° 57′ 43″	333° 30′ 43″	0·52	0·360	0·43
	Asteroids, .	① to (299)	2·200 to 3·500	204·4 to 325·2	·04 to ·34	5° to 35°	....	....	....	....	....
Outer Planets.	Jupiter, .	♃	5·203	483·3	·0483	1° 18′ 41″	98° 41′ 6″	12° 0′ 25″	0·04	0·034	0·037
	Saturn, .	♄	9·539	886·0	·0561	2° 29′ 40″	112° 5′ 28″	90° 22′ 17″	0·012	0·0099	0·011
	Uranus, .	♅	19·183	1781·9	·0463	0° 46′ 20″	72° 44′ 10″	168° 18′ 39″	0·0027	0·0025	0·003
	Neptune, .	♆	30·055	2791·6	·0090	1° 47′ 2″	130° 6′ 50″	47° 14′ 40″	0·0011	0·0011	0·001

NAME OF PLANET.	MOVEMENT IN ORBIT.						DIAMETER.			
	Sidereal Revolution in mean Solar Days.	*Period in Years.*	*Orbital Velocity in Miles per Second.*	*Earth's Velocity as 1.*	*Mean daily Heliocentric Motion.*	*Synodical Revolution.*	*Apparent Diameter.*	*Mean Diameter in Miles.*	*The Earth's, as 1.*	*Compression.*
Mercury, . .	87·97	0·24	23 to 35	1·6	4° 5′ 32″	Days. 115·87	5″ to 13″	3,000	0·83	Unknown.
Venus, . .	224·7	0·62	21·9	1·17	1° 36′ 7″	583·92	11″ to 67″	7,700	0·97	,,
The Earth, .	365·256	1·00	18·5	1·0	0° 59′ 8″	......	......	7,918	1·00	$\frac{1}{293}$
Mars, . .	686·95	1·88	15·0	0·81	0° 31′ 26″	779·94	4″ to 25″	4,230	0·53	$\frac{1}{220}$
Asteroids, .	1200·0 to 2400·0	3·29 to 6·56	....	....	....	....	....	From a few miles to 300	....	....
Jupiter, . .	4332·58	11·86	8·1	0·44	0° 4′ 59″	398·87	32″ to 50″	86,500	10·92	$\frac{1}{17}$
Saturn, . .	10759·22	29·46	6·0	0·32	0° 2′ 1″	378·10	14″ to 20″	71,000	8·97	$\frac{1}{9}$
Uranus, . .	30686·82	84·02	4·2	0·23	0° 0′ 42″	369·66	4″	31,900	4·03	$\frac{1}{11}$
Neptune, . .	60181·11	164·78	3·4	0·18	0° 0′ 21″	367·49	3″	34,800	4·39	Unknown.

PRINCIPAL FACTS ABOUT THE PLANETS.

PLANET.	Period of its Rotation on Axis.			Inclination of its Equator to its Orbit.	Longitude of its Vernal Equinox.	SURFACE.	VOLUME.	MASS.	DENSITY.		FORCE OF GRAVITY at Surface of Planet.	
						Compared with the Earth as 1.	Compared with the Earth as 1.	Compared with the Earth as 1.	Compared with the Earth as 1.	Compared with Water as 1.	Compared with Earth's as 1.	Bodies fall in One Second.
	h.	m.	sec.									
Mercury,	Unknown.			Unknown.	......	0·14	0·056	0·13	2·23 ?	12·4	0·85	13·7 feet.
Venus,	23	21	23	50° + ?	......	0·94	0·92	0·78	0·86	4·9	0·83	13·4 „
The Earth,	23	56	4·09	23° 27′ 12″	180° 0′	1·00	1·00	1·00	1·00	5·6	1·0	16·09 „
Mars,	24	37	22·72	24° 50′ 0″	79° 15′	0·28	1·15	0·107	0·72	4·0	0·38	6·2 „
Asteroids,	......			......	......	......	......	......	......	......	......	......
Jupiter,	9	55	26 +	3° 5′ 30″	314° 0′	118·3	1309	316·0	0·42	1·3	2·65	45·0 „
Saturn,	10	14	24	26° 48′ 40″	167° 4′	80·4	721	94·9	0·13	0·7	1·18	18·3 „
Uranus,	Unknown.			Unknown.	165° 25′ ?	16·3	65	14·7	0·22	1·2	0·91	14·6 „
Neptune,	Unknown.			Unknown.	175° 40′ ?	19·3	85	17·1	0·20	1·1	0·88	14·2 „

PRINCIPAL ELEMENTS OF THE SATELLITES OF THE PLANETS.

PLANET, AND NAMES OF SATELLITES.	Distance from Centre of Planet in Miles.	Period of Satellite's Revolution.				Inclination of Orbit to Ecliptic.	Diameter in Miles.
		d.	h.	m.	sec.		
EARTH—							
Moon,	238,840	27	7	43	11·5	5° 8′ 40″	2,162
MARS—							
Phobos,	5,850	0	7	39	15	26° 17′ 0″	7 ?
Deimos,	14,650	1	6	17	54	25° 47′ 0″	5 ?
JUPITER—							
Io,	261,000	1	18	27	34	2° 8′ 0″	2,500
Europa,	451,000	3	13	13	42	1° 39′ 0″	2,100
Ganymede,	664,000	7	3	42	33	2° 0′ 0″	3,550
Calypso,	1,167,000	16	16	32	11	1° 57′ 0″	2,960
SATURN—							
Mimas,	117,000	0	22	36	18	28° 10′ 0″	600
Enceladus,	157,000	1	8	53	3	28° 10′ 0″	800
SATURN, *contd.*—							
Tethys,	186,000	1	21	18	33	28° 10′ 0″	1,100
Dione,	238,000	2	17	44	51	28° 10′ 0″	1,200
Rhea,	332,000	4	12	25	11	28° 10′ 0″	1,500
Titan,	771,000	15	22	41	25	27° 39′ 0″	3,500
Hyperion,	934,000	21	6	39	27	27° 5′ 0″	500
Japetus,	2,225,000	79	7	54	41	18° 32′ 0″	2,000
URANUS—							
Ariel,	120,000	2	12	29	21	97° 51′ 0″	500 ?
Umbriel,	167,000	4	3	27	37	97° 51′ 0″	400 ?
Titania,	273,000	8	16	56	30	97° 51′ 0″	1,000 ?
Oberon,	365,000	13	11	7	7	97° 51′ 0″	800 ?
Neptune's Satellite,	225,000	5	21	2	44	145° 12′ 0″	2,000 ?

CHAPTER VI.

COMETS AND METEORS.

"Mysterious visitant, whose beauteous light
Among the wondering stars so strangely gleams!
Like a proud banner in the train of night,
Th' emblazon'd flag of Deity it streams—
Infinity is written on thy beams;
And thought in vain would through the pathless sky
Explore thy secret course."—*Conder.*

In ancient times comets were indeed mysterious visitants, and were the terror of all beholders. From their sudden appearance, their rapid movements, and their gigantic luminous appendages, they were well fitted in the unenlightened ages to produce this effect, and were considered representations of Divine displeasure. What is now admired was then dreaded, and looked upon as messengers of death and destruction—as visitors from the celestial spaces, whose presence indicated to the superstitious nations, coming famines, wars, or plagues. Now we know differently, as science has for ever dispelled these absurd beliefs. It has, by revealing their nature, shown that the heavenly bodies, in their silent courses, have not the slightest influence over human affairs; that especially those wandering cometary orbs, however erratic they may appear, certainly travel round the sun as much in accordance with the great laws of the universe as do the more regularly revolving planets.

THE PATHS OF COMETS.

The prophecy of Seneca has thus been fulfilled. About two thousand years ago that philosopher wrote—"A day will come when the course of these bodies will be known and submitted to rules, like that of the planets." That day has long since come, for about three hundred years ago Tycho Brahé, from his careful observations of the comet of 1577, was enabled to demonstrate that comets move at much greater distances than that of the moon, and in orbits vastly different from those of the planets, in as much as the comet he observed travelled completely through the then supposed planetary crystalline spheres. Kepler, Tycho's disciple, considered that the paths of comets were straight, and that their number was as great as the fishes in the sea; but it was not till nearly one hundred years afterwards, or about the year 1668, that Hevelius first suggested the true nature of cometary orbits—viz., the *parabolic.* From observations of the comet which appeared in 1681, tested by Doerfel, this supposition was proved to be correct. The theory of universal gravitation having by this time been advanced, a method of computing the different elements of a comet's path from three observations was soon invented by Newton, and applied to all comets that appeared.* It was in this manner that the true nature of the cometary orbits was finally determined, and several comets identified—a triumph of astronomical science that was all the more brilliant from the impossibility of recognising a comet on its return simply from its appearance. This identification of a comet was first accomplished by the astronomer Halley, who discovered that, while some comets moved round the sun in parabolic orbits, others undoubtedly formed part of the solar system, and journeyed round the sun in elliptical paths. This he was enabled to prove from observations of the comet of 1682. When that orb appeared, Halley, after the method invented by Newton, calculated the elements of its path, in order to predict its position in the heavens from night to night. In this Halley was so successful that it induced him to try and determine the orbits of all the former comets of which accurate observations could be secured. With great labour he computed the elements of no less than twenty-four cometary orbits. In examining these he found there were two paths, which were almost identical with the comet which had just appeared. Each of these comets had been very conspicuous, and what made the coincidence the more remarkable, was the fact that the intervals between the appearances of these orbs were nearly equal, for they had appeared in the years 1531 and 1607. Thus between the years 1531 and 1607, there is an interval of 76 years; and between 1607 and 1682, there is an interval of 75 years; and further, as these three comets had almost the same orbits, Halley was led to believe that they were simply three different appearances of one and the same comet, one probably travelling round the sun in an elliptical path in a period of about 76 years. The elements of these comets are as follows:—

---

* The so-called elements of a comet's path are :—1st, the heliocentric longitude of the ascending node of the orbit; 2nd, the inclination of the plane of the cometary path to the plane of the ecliptic; 3rd, the longitude of the perihelion of the orbit; 4th, the distance of this point from the sun, or the perihelion distance; and 5th, the exact date when the comet is in this position, or the epoch of perihelion passage.

Year in which the comet appeared, ...	1531	1607	1682
Longitude of ascending node, ...	49° 25′	50° 21′	51° 16′
Inclination of orbit to the ecliptic, ...	17° 55′	17° 3′	17° 56′
Longitude of perihelion, ...	301° 39′	302° 16′	302° 53′
Distance of perihelion from the sun—the earth's distance as 1·000,	0·567	0·587	0·583
Direction of movement, ...	Retrograde.	Retrograde.	Retrograde.

Halley, however, went further. He not only held that these three comets were different appearances of one orb, but that as the comet journeyed in a closed orbit like a planet, it would be again seen 76 years later, or in the year 1758. This remarkable prediction was verified; for though the comet did not appear exactly at the time given by Halley, but over twenty months later, or in the month of March, 1759, the discrepancy was fully accounted for, as its motion had been retarded by the attractions of the larger planets. As might be expected, this fulfilment of Halley's prediction marked an epoch in cometary astronomy; for it proved, beyond the possibility of a doubt, that there were some comets bound to our system by the bonds of gravity, and revolving in regular periods round the sun. In 1835 this interesting orb again returned. A view of it as it then appeared is given in Plate 16, while the position and extent of its orbit will be seen in Plate 13.

THE MOVEMENTS OF COMETS.

Comets, therefore, move in parabolic, elliptical, and very often hyperbolic orbits. In fact, it is highly probable that though comets are sometimes considered to travel in the first-mentioned curve, they never really do so, but on the contrary move either in a long elliptical, or hyperbolic path. In every instance the sun is situated in the focus of the curve, and in this respect the paths of comets are identical with the orbits of the planets. Unlike the planetary paths, however, the orbits of comets are not confined to a general plane, but are inclined to the plane in which the planets move at all angles; some comets, indeed, move in planes nearly perpendicular to those of the planets. The direction of the movement of comets is also in some cases different from the movements of the planets. The various members of the planetary system revolve round the sun all in one direction,—viz., from west to east (*see Plate* 13). This is also the direction in which the sun, and planets, out to the orbit of URANUS, rotate on their axis, and also that in which the various satellites of these planets revolve in their orbits. Many comets also move round the sun in this direction, but as great a number are found to travel in a direction exactly opposite, or from east to west, as in the case of Halley's comet (*see Plate* 13).

THE MORE IMPORTANT COMETS BELONGING TO THE SOLAR SYSTEM.

FIRST CLASS. WITH SHORT PERIODS.

NAME OF COMET.	*Mean Distance from the Sun (Earth's as 1·000).*	*Period of Revolution.*	*Eccentricity of Orbit.*	*Inclination of Orbit to Plane of Ecliptic.*	*Direction of Motion.*
Encke's	2·22	3·31 years.	0·846	12° 54′	Direct.
Blainpain's . . .	2·84	4·81 ,,	0·687	9° 11′	,,
Burckhardt's . . .	2·93	5·03 ,,	0·864	8° 2′	,,
Clauseus'. . . .	3·09	5·44 ,,	0·721	1° 54′	,,
Brosen's	3·10	5·46 ,,	0·810	29° 23′	,,
Tempel-Swift's . .	3·12	5·51 ,,	0·656	5° 24′	,,
Lexell's	3·16	5·61 ,,	0·786	1° 34′	,,
Pons's	3·16	5·62 ,,	0·755	10° 43′	,,
Winnecke's . . .	3·23	5·81 ,,	0·727	14° 27′	,,
Tempel's	3·49	6·51 ,,	0·405	10° 50′	,,
Biela's	3·53	6·63 ,,	0·755	12° 34′	,,
D'Arrest's . . .	3·55	6·69 ,,	0·626	15° 42′	,,
Faye's	3·85	7·57 ,,	0·549	11° 20′	,,
Pigott's	4·65	10·03 ,,	0·679	47° 43′	,,
Suttle's	5·74	13·76 ,,	0·822	55° 14′	,,
Peters's	6·32	15·99 ,,	0·757	13° 2′	,,

The above Comets are all invisible to the naked eye, being what are known as Telescopic Comets.

SECOND CLASS. WITH MEAN PERIODS.

NAME OF COMET.	*Mean Distance from the Sun (Earth's as 1·000).*	*Period of Revolution.*	*Eccentricity of Orbit.*	*Inclination of Orbit to Plane of Ecliptic.*	*Direction of Motion.*
Westphal's . . .	16·62	67·77 years.	0·925	40° 58′	Direct.
Pons-Brook's . . .	17·22	71·48 ,,	0·955	74° 3′	,,
Olber's . . .	17·41	72·63 ,,	0·931	44° 34′	,,
De Vico's . . .	17·54	73·25 ,,	0·954	84° 57′	,,
Brorsen's	17·78	74·97 ,,	0·973	19° 8′	,,
Halley's	17·99	76·37 ,,	0·967	17° 45′	Retrograde.

THIRD CLASS. WITH LONG PERIODS

Year in which Comet appeared.	*Perihelion Distance (Earth's mean distance as 1·000).*	*Period of Revolution.*	*Eccentricity of Orbit.*	*Inclination of Orbit to Plane of Ecliptic.*	*Direction of Motion.*
1580 A.D.	0·602	9,000 years.	0·998	64° 34′	Direct.
1680	0·006	8,800 ,,	0·999	60° 40′	,,
1811	1·035	3,000 ,,	0·995	73° 2′	Retrograde.
1822	1·145	5,500 ,,	0·996	52° 39′	,,
1830	0·921	6,000 ,,	0·999	21° 16′	Direct.
1840	1·481	14,000 ,,	0·998	59° 13′	Retrograde.
1844	0·855	102,000 ,,	0·999	48° 36′	,,
1858 (Donati's)	0·578	2,000 ,,	0·996	63° 2′	,,
1863	0·795	1,800,000 ,,	0·999	85° 22′	Direct.
1864	0·931	2,800,000 ,,	0·999	70° 18′	Retrograde.

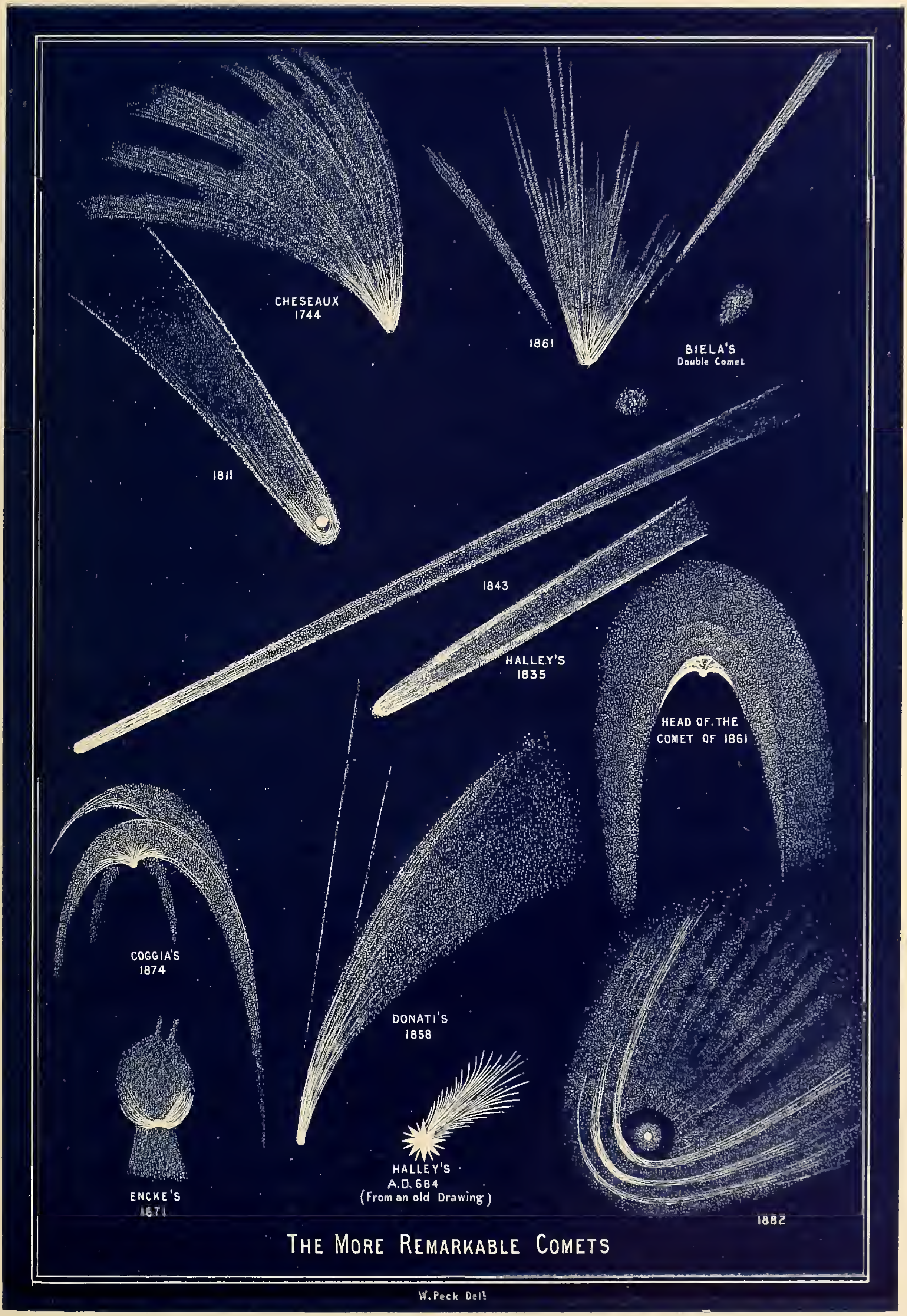
Periodic comets, or those revolving in elliptical paths, may be divided into three separate groups—viz., comets with short periods; those with mean periods; and those with long periods. The more important members of the various classes are given in the Table on p. 65.

The one with the shortest period of revolution—Encke's—was discovered to be periodical in the year 1818, though it had frequently been observed on former occasions, as far back as the year 1789. As this small comet came to be watched it was discovered that its period of revolution was gradually decreasing in length. This could only be accounted for by supposing that there existed in what had hitherto been called empty space, a very rare medium, which, however, was dense enough to sensibly retard the movements of the smaller comets. This resisting medium is now known to exist. In Chapter V. it was mentioned that the sun is surrounded with an exceedingly complex atmosphere, which is so extensive as probably to reach to the confines of the system. The more distant, of course, a portion of this atmosphere is from the sun, the rarer it becomes, and beyond the orbit of our globe it is doubtless so attenuated as to be incapable of producing much retardation on the motions of even the lightest comets. Near the sun, however, it is different; the density of the solar envelope is greater, and therefore when a small comet, as in the case of Encke's, happens to pass so near the sun as to be within the orbit of MERCURY, the resistance encountered is sufficient to give the central orb power to draw the comet into a smaller path, and accordingly accelerate its movement, and shorten its period of revolution. All the comets of the first two classes, with the exception of Halley's (*see Table*), move round the sun in the same direction as the planets, or from west to east, and their movement is therefore said to be "direct." Those which travel in the opposite direction, or from east to west, have accordingly a retrograde movement.

The comets of the third class have periods extending from 200 years and upwards. In most cases the intervals of revolving round the sun are not known with certainty, as that part of the elliptical path traversed by the comet during the time it is visible, differs very little from a true parabola. It is, therefore, with the utmost difficulty that even the approximate mean distance can be determined, and as the periods are so long, two visitations from a member of this class have not, so far as is known, been observed. In fact, the interval occupied by some periodic comets in revolving round the sun is so enormous, that when last visible from our globe no astronomers were probably here to observe them. Indeed some comets may have periods amounting to over *three millions* of years, and may travel so far into space as to be over one thousand times more distant from the sun than NEPTUNE, or to a distance from the central orb of about one-fifth of the distance which separates us from the nearest star—a distance that even light would require about ten months to journey over. Indeed, there is no limit to the distance to which some comets may travel; only if they recede from the sun beyond a certain distance, or move away from him above a certain velocity, they will be brought within the sphere of some other sun's influence, and journeying towards the new centre of attraction, will never again visit our system.

THE HEADS OF COMETS.

In general the head of a comet, when viewed with the telescope, appears as a bright condensed and sometimes star-like nucleus, surrounded with several vaporous envelopes. This bright portion is really the principal part of the comet, for it alone strictly obeys the solar attraction, and moves in a true elliptical or hyperbolic orbit. In most large comets the nucleus consists of a solid, liquid, or vaporous mass, depending on its distance from the sun. When very near the sun, it of course glows with intense heat—so intense, indeed, that the most refragable material known will easily be vaporised. The head of the comet of Newton which appeared in 1680, for instance, approached the surface of the sun as close as one-third of the solar diameter, and was accordingly subjected to a heat nearly 26,000 times greater than that of the sun in our tropical regions, or over 2000 times greater than the temperature of red-hot iron. Under the action of the solar heat the nucleus appears to decrease, a result which would not be expected, as the effect of an increase of temperature is rather to expand the mass. This will certainly be the case with the heads of all comets on their approach to the sun; but as the real nucleus will also become brighter, and the vaporous masses surrounding


CHESEAUX
1744
1861
BIELA'S
Double Comet
1811
1843
HALLEY'S
1835
HEAD OF THE
COMET OF 1861
COGGIA'S
1874
DONATI'S
1858
ENCKE'S
1871
HALLEY'S
A.D. 684
(From an old Drawing)
1882

THE MORE REMARKABLE COMETS

W. Peck Delt

it be made more transparent, the apparent size of the head will be less. The appearance of the brightest part of the head alters also with increase of telescopic power; for the larger the instrument employed, the smaller it appears; this indicates that even in a large comet the real nucleus is very small indeed, and is greatly obscured by the vapours surrounding it.

The luminous material in which the nucleus is enclosed, is, from its hairy appearance, called "the coma." In many instances the spectroscope shows that the vapour of which it is composed consists largely of hydrogen and carbon in one of their more numerous compounds. In large comets streams of matter are often observed moving in the coma, travelling outwards from the nucleus, like waves receding from the place where a stone has been dropped into some still water. These envelopes, as they have been termed, are doubtless spherical segments of matter, slightly more dense than the vapour forming the other parts of the coma—(*see the heads of the comets of* 1861 *and* 1882 *in Plate* 16). Even these densest portions, however, consist of some very rare vapour, as is proved by the fact that faint stars can occasionally be seen shining through them. In the direction exactly opposite from the sun the coma generally streams past the nucleus, and forms the commencement of the tail.

THE TAILS OF COMETS.

The tail is certainly the most wonderful portion of a comet—the part which, from its strange appearance and gigantic dimensions occasionally attained, was, in superstitious ages, well fitted to produce terror and awe. In telescopic comets the tail, as might be expected, is generally small, and sometimes altogether wanting, in which case the comet is simply a mass of vapour without any distinct nucleus. In travelling towards the sun, the tail is always stretching behind the nucleus, and before it when the comet is travelling away from the centre of attraction. This was first noticed to be the case by Appian, from observations of the comet which appeared in 1531, as he found that independent of the position the comet occupied in its orbit, the tail was always pointing away from the sun, and was simply a prolongation of the radius vector, in every instance the convex side being nearest to that line.

THE APPARENT AND ACTUAL LENGTHS OF THE TAILS OF COMETS.

Name of Comet.	*Apparent Length of Tail in Degrees.*	*Actual Length in Millions of Miles.*	*Name of Comet.*	*Apparent Length of Tail in Degrees.*	*Actual Length in Millions of Miles.*
1860 (III.)	15°	22	837	79°	...
1744	24°	19	1680	90°	150
1811 (I.)	25°	109	1769	97°	40
1811 (II.)	...	130	1264	100°	...
1456	57°	...	1618 (II.)	104°	50
1843 (I.)	65°	200	1647 (I.)	...	131
1858	64°	55	1861 (II.)	118°	42
1689	68°	...			

In many instances the tails of comets extend to an enormous distance from the nucleus. The tail of the comet of Newton, for example, was no less than 100 millions of miles in length, and consequently extended from the sun to a distance greater than that which separates our earth from the centre of the system. But the great comet which appeared in 1843 had even a larger tail—one, in fact, of nearly double the length. The lengths of the tails of the largest comets are given in the above Table.

But while the tails of comets occasionally extend to enormous distances, they are always formed of the very rarest materials. This is proved to be the case from the fact that often the faintest stars are seen shining through even the densest portion, without their light being greatly diminished, notwithstanding the enormous depth of vapour which the light has to pass through. This shows that the total amount of matter in the tails of even the largest comets must be very insignificant. In many cases, indeed, it may only weigh a few ounces, though the tail be hundreds of millions of miles in length. It is, in fact, from its extreme lightness that the tail stretches to so great a distance; for the matter composing it is being continually formed of *new* material. Under the action of the solar heat, the matter in the nucleus is partly converted into vapour, and the more volatile the substance the greater the distance to which it is expelled. This expulsion of the vapour from the nucleus is brought about by a force directed from the sun, acting on the rarer materials and driving them to great distances. This is the cause of the tail pointing away from the sun, and why it often appears curved and of double or multiple form. The different materials of the nucleus will, in proportion to their mass, be, of course, expelled with different velocities, and tails of various forms will be produced. As hitherto observed, the tails of comets can be arranged into three forms. First, long, straight tails; second, long, curved tails; and, third, short, broad, curved tails, deviating greatly from the radius vector. The first class is well represented by the comet of 1843 (*see Plate* 16). This type of tail is evidently composed of some very light vapour, probably the lightest known gas, or hydrogen, which, from its rarity, will, under the repulsive force, attain the greatest possible velocity—a velocity great enough to prevent the tail from becoming curved. The matter of the second type is possibly heavier, being doubtless hydro-carbon gas. Accordingly, as in the case of Donati's comet (*see Plate*), the tail assumes a graceful curve. In the third type, the matter is still heavier, for the velocity of the particles is least, as revealed by the shortness of tail, and the amount of deviation or dragging behind the nucleus. Doubtless this type of tail is composed of the vapour of iron.

METEORS.

The tails being always composed of fresh material, comets are accordingly becoming gradually smaller. At each perihelion passage large quantities of the more volatile substance in the nucleus are dissipated, and, consequently, the tail becomes shorter at each successive return. Halley's comet is a striking example of this. In the past its tail was large, and it appeared as a conspicuous object; but on the last return, in 1835, the tail was comparatively insignificant. In the case of Biela's comet, on the other hand, the combined action of the solar rays, and the repulsive force, finally produced a disintegration of the vaporous mass. This is doubtless the end of all comets; their materials being distributed along their orbits in the form of revolving streams of small particles of matter. These streams are very thickly strewn throughout the solar system, and must thus be frequently encountered by the planets. Indeed, our own planet comes into contact very often with these meteoric clouds, and in so doing brings about a shower of shooting stars. From the attraction of our earth, the particles of matter in the stream are drawn with great velocity to her surface. As they near our globe their speed is so very great that whenever they enter the atmosphere the resistance they meet with generates an intense heat, which is generally more than sufficient not only to ignite the meteoric matter, but to completely dissipate it before reaching the ground.

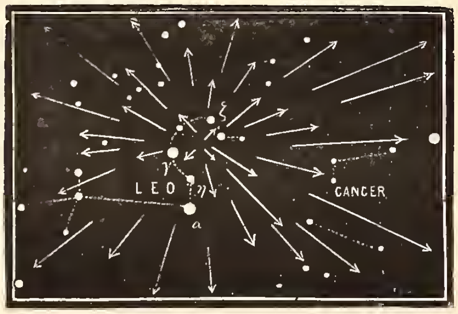


FIG. 17. THE RADIANT POINT OF THE NOVEMBER METEORS.

As the cometary or meteoric streams cut the orbit of the earth at various places, our globe will therefore pass through each one that does so, once in every revolution, or annually. Accordingly, the display from a given system will occur regularly on certain dates, and will also appear to come from the same part of the heavens. Those meteors, for instance, which are seen on the 12th and 13th of November appear to radiate from a part of the heavens near the star γ LEONIS (*see Fig.* 17); those of the 27th of the same month from

METEOR SYSTEMS.

PERIOD, and Duration of Visibility.	*POSITION OF RADIANT POINT.*		*In what Constellation Situated.*	*Nearest Bright Star.*	*NAME OF SYSTEM, AND REMARKS.*
	Right Ascension.	*Declination.*			
	h. m.				
January 2nd to 3rd	15 28	49° N.	DRACO	ι	*Quadrantids.*
,, 8th ,, March 31st	11 40	14° N.	LEO	ϐ	...
February 6th ,, April 25th	12 0	56° N.	URSA MAJOR	δ	...
March 11th ,, May 31st	17 32	50° N.	DRACO	ξ	*Draconids.*
April 5th ,, May 10th	18 8	35° N.	LYRA	ϰ	*Lyrids.*
,, 12th ,, June 30th	15 40	23° N.	CORONA	α	*Coronids.*
,, 29th ,, May 2nd	21 44	2° S.	AQUARIUS	α	*Aquarids.*
June 7th ,, August 12th	20 8	8° N.	AQUILA	5° E. of α	*Aquilids.*
,, 28th	22 32	17° N.	PEGASUS	7° N. of ζ	*Pegasids.*
July 5th	20 36	48° N.	CYGNUS	α	*Cygnids.*
,, 21st	0 28	33° N.	ANDROMEDA	δ	*Andromedes* I.
,, 23rd to August 20th	2 56	56° N.	PERSEUS	γ	*Perseids.* Maximum display about August 10th. Connected with comet (iii.) 1862.
August 6th to Sept. 30th	22 20	52° N.	LACERTA	ϐ	*Lacertids.*
,, 6th ,, Oct. 10th	23 56	13° N.	PEGASUS	γ	*Pegasids.*
,, 22nd ,, Oct. 20th	3 4	35° N.	PERSEUS	Between ζ and ϐ	*Muscids.*
September 17th	5 36	48° N.	AURIGA	E. of α	*Aurigids.*
,, 25th to Oct. 25th	7 0	27° N.	GEMINI	N. of δ	*Geminids.*
October 5th ,, Nov. 5th	2 36	15° N.	ARIES	...	*Orionids.* Maximum about October 19th.
,, 15th	2 4	9° N.	ARIES	...	*Arietids.*
,, 21st to Nov. 30th	4 0	20° N.	TAURUS	Between ε and the Pleiades	*Taurids.*
Nov. 11th ,, 15th	9 56	23° N.	LEO	W. of γ	*Leonids.* Last great display in 1866.
,, 24th ,, Dec. 7th	1 40	43° N.	ANDROMEDA	W. of γ	*Andromedes* II. Last great display in 1885, connected with Biela's comet.
,, 27th ,, Dec. 27th	7 0	32° N.	GEMINI	5° to W. of α	*Geminids.* Maximum about December 10th.
Dec. 6th ,, 12th	5 20	23° N.	TAURUS	ζ	*Taurids.*

the constellation of ANDROMEDA; and those seen on the 10th of August, from the constellation of PERSEUS.

The Table on page 69 contains the more important "radiant points" of meteor systems, or that part of the heavens from which the meteors appear to burst.

OCCURRENCE OF METEOR SHOWERS.

As might be expected, the display from a meteor system is not annually the same, owing to the likelihood of the matter composing the stream being unequally distributed in its orbit. This is, indeed, found to be the case with the principal meteor systems. The meteors of the 13th November, for example, have a maximum display once every thirty-three years, and the last great shower from this system took place in 1866. The meteors of the 27th November, again, had their last maximum display in 1885, on which occasion the heavens were alive with brilliant celestial fireworks. This system is identified with the periodic comet of Biela, a comet that has been lost since 1852. Discovered in 1826, this comet had been seen on its various returns to perihelion till 1846, when it was noticed that it became divided into two parts. In 1852 the double comet was again seen, but since then it has never been observed, the vaporous masses having doubtless been further dispersed and scattered along their orbits. On the 27th of November, 1885, however, part of this comet was seen indirectly, by our earth coming into contact with it, and producing the magnificent meteoric shower.

On the above-mentioned occasion the number of meteors caught by our globe must have been enormous. This shows us that the annual quantity of material received by our planet is very great indeed. In the past it was doubtless even greater, as by repeated encounters, not only with the earth, but many of the other planets, the various meteor streams have been greatly destroyed. In fact, at one time the amount of this meteoric material in the solar system would probably be so great as to have sensibly increased the diameter and mass, not only of our own globe, but of each of the planets. For the most part the individual shooting stars are of small dimensions, and probably weigh but a very few ounces. Though coming from the regions of interplanetary space they do not, as might have been supposed, bring any new element, but are composed of many well-known terrestrial substances, as iron, nickel, &c. This is found to be the case from analysis of the meteoric dust brought down from the higher atmosphere by snow, and found on the top of high mountains where the soil has not been disturbed.

METEORITES.

Sometimes individual meteorites are of a much greater size and weight than those above mentioned, being in many instances actually large enough to prevent the resistance of the atmosphere from completely destroying them, and accordingly the mass reaches the ground in a solid state. These meteoric masses which thus occasionally fall have all the appearance of ordinary stones, and are generally of a greyish colour. They have been arranged into three classes, according to the nature of their composition. First, *Aërolites,* which are simply masses of stone composed of different silicates, interspersed with particles of nickeliferous iron, and protosulphide of iron; second, *Siderites,* or masses of iron containing phosphides of nickel, and sometimes carbon; and, third, *Siderolites,* or large sponge-like masses of nickeliferous iron, with various silicates in the cavities. The siderites are by far the heaviest of the meteorites, one at the Kensington Museum actually weighing three and a-half tons. It is fortunate for science that these masses occasionally fall, as they can be analysed, and accordingly not a little learned, not only of their present structure, but what is of greater importance—viz., of their condition in the past. When analysed their composition is found to be, for the most

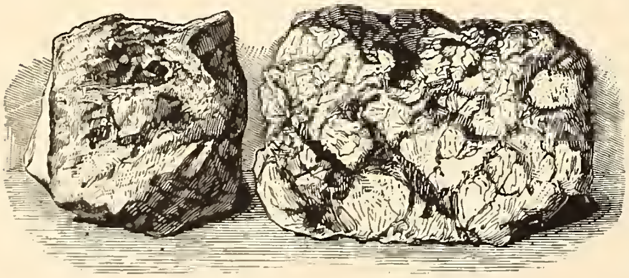


FIG. 18. METEORIC STONES.

part, of the same nature as meteoric dust, and therefore no new element has been found, which shows that even in the distant celestial regions the same kind of matter exists as on our earth—a testimony which is also borne out by spectroscopic analysis of the stars. The following are the different elements which have been found in meteorites:—

Hydrogen.
Oxygen.
Chlorine.
Sodium.
Potassium.
Carbon.
Nickel.
Iron.
Cobalt.
Copper.
Tin.
Calcium.
Magnesium.
Aluminum.
Arsenic.
Antimony.
Titanium.
Lithium.
Manganese.
Chromium.
Sulphur.
Phosphorus.
Vanadium.
Silicon.

ORIGIN OF COMETS AND METEORS.

Besides revealing the nature of their composition, analysis also shows that at one time these solid meteoric masses existed in a state of hot vapour, which on cooling condensed into many minute particles, which afterwards collected into larger masses and solidified. This result is what might be expected from the connection which exists between meteors and comets. Analysis throws some light also on the origin of comets themselves. When, for instance, certain of the iron meteors are heated in a vacuum, they give off a very large quantity of hydrogen, which shows that they must have been ejected from some dense atmosphere of that gas. In Chapter III. it was mentioned that the stars of the first type had exceedingly dense atmospheres composed of hydrogen, and so one is led to suppose that it was from some of those distant orbs that these particular meteorites have come. At first this would seem to be impossible, but it is not by any means so. Our sun, as mentioned in Chapter V., has power to occasionally eject matter from his surface to very great distances, and what is true of our sun is also true of every star in the heavens, especially the stars of the first class. From some distant sun, then, a quantity of the glowing vapour surrounding it would, from the effect of a gigantic eruption, be ejected with a velocity greater than that which the star itself could impart to objects falling towards its surface. In consequence of this, the vaporous mass would for ever travel away from the sun from which it was expelled, and, in so doing, would condense, perhaps into one large mass and form a comet, or into numerous minute particles, and produce a swarm of meteors; or it may be, produce both of these results.

The origin of the larger comets and meteor streams travelling from the regions of inter-stellar space is thus accounted for, but it does not explain the existence of the very small periodic comets. A striking peculiarity of these small orbs is that the aphelia of their orbits are always situated near the path of some large planet. In every case, when farthest from the sun, the comet is close to the planet's orbit, a fact which points to some connection between these small comets and the giant members of the outer planets. Indeed, it is thought that most of the small periodic comets are simply the outcome of eruptions on the giant planets, at a time in the distant past, when those orbs were in a condition greatly different from that in which they are at present—when they were in a more youthful stage, and were glowing with intense heat, and giving out light like miniature suns.

CHAPTER VII.

THE MOON.

"All hail! thou lovely queen of night,
Bright empress of the starry sky!
The meekness of thy silv'ry light
Beams gladness on the gazer's eye."—*Miller.*

THE LUNAR PHASES.

On certain evenings during every month, shortly after sunset, the moon may be seen shining in the western part of the sky, as a very slender crescent of light. This crescent will be observed to increase in dimensions from night to night, till in about seven days after it was first noticed, it will appear as a half-illuminated disc. As is well known this is called half-moon, or the moon's first quarter. The lighted portion of the moon steadily increases, and in about other seven days it is seen perfectly round, or the moon appears full. From this time the bright part of the lunar disc gradually decreases, till in about a week after full moon, at the time of the last quarter, the moon once more appears as a half-luminous disc; and in about fifteen days after the full, she is invisible, being then nearly between our earth and the sun. This portion of the lunar globe, when in conjunction with the sun, is termed new moon; and from careful observations it has been found that the mean interval between each of these phenomena is 29 days 12 hours 44 minutes 2·7 seconds.

These different appearances of the moon are known as *phases*, and are produced by the revolution of the moon round the earth, which has the effect of bringing into view various portions of the illuminated half of her globe. At the time of new moon, for instance, when the lunar globe is between us and the sun, all the lighted side is directed away from us; but as the moon in revolving round our earth travels to the eastward of the solar orb, more and more of the western part of the illuminated side is brought into view, till, when directly opposite to the sun, the whole of the lighted half is turned towards us, and the moon then appears full. From the point of opposition to the solar globe, the moon in completing her orbital revolution now gradually approaches the sun, and accordingly the western side of the illuminated disc begins to diminish. In about a week afterwards, by the time the moon has journeyed to within ninety degrees from the sun as viewed from our earth, the disc again appears half-illuminated, as when in the opposite part of her monthly path at the time of the first quarter, with this difference, now the bright half is turned in the contrary direction, or to the east.

As above mentioned the intervals between successive conjunctions of the sun and moon, or the complete period of a *lunation*, is a little over twenty-nine and a-half days. This period, however, is longer than the time occupied by the moon in making a complete revolution round our globe. The length of the lunar orbital revolution can be accurately determined by observing the time occupied by the moon in travelling from a star, right round the heavens, back to the same star again. This is termed the sidereal revolution of the moon, the time required for which amounts to 27 days 7 hours 43 minutes 11·5 seconds, or over two days shorter than a lunation or synodical revolution. The difference between these periods is produced by the moving of our globe round the sun, for if the earth had no orbital movement the two periods would be of exactly the same length. Our globe, however, like each of the planets, is constantly travelling round the great centre of the system, moving at the angular velocity of about one degree per day; which has the effect of causing the sun apparently to move round the heavens among the stars in an easterly direction, at the same angular velocity. The moon, on the other hand, from her own orbital movement, journeys round the heavens in the same direction as the sun, but at the apparent velocity of over thirteen degrees per day. By the time, therefore, the moon has travelled from conjunction with the solar orb completely round the heavens, or made a sidereal revolution, the sun has apparently journeyed twenty-seven degrees to the eastward of the position he occupied when the lunar globe was last in conjunction with him. Accordingly, the moon moving at the rate of thirteen degrees per day will occupy two days longer than a complete revolution, or in all twenty-nine and a-half days, in order to be again in a line with the sun.

THE MONTH.

From what has been mentioned, it will be seen that there are different kinds of months, depending on the manner in which they are determined. The oldest one was undoubtedly the *synodic,* as it was easily determined from the phases, it being, as already mentioned, the interval between successive conjunctions of the sun and moon. This, indeed, was the earliest year, or longest time-interval of primitive man, and from the change occurring once in about every seven days, the worshipping of the moon at these intervals ultimately gave rise to the invention of the week. The *sidereal* month, or interval between successive conjunctions of the moon and a star, as already mentioned, is shorter than the synodic, but it is the true length of the moon's orbital revolution, and this period being determined from the stars, is consequently subject to no variation. The *tropical* and *nodical* months, or intervals between conjunctions of the moon and a tropic, and the moon and the node, respectively, are still shorter, on account of the movements of these points being in the opposite direction to that of the moon in her orbit.

Owing to the precession of the equinoxes, the tropical and solstitial points are carried round the heavens from east to west; and, accordingly, the period of revolution when determined from either of these points will be slightly shorter than the sidereal period. The nodical month is also shorter for a similar reason, as the nodes of the lunar orbit revolve round the ecliptic from east to west, or retrograde, in a period of over eighteen and a-half years. Accordingly, while the moon has journeyed from a node completely round the heavens, the node has, meanwhile, travelled about one and a-quarter degrees to the west of its former position, and the moon will come once more in conjunction with it, nearly three hours before a sidereal revolution has been completed. The *anomalistic* month, or the interval occupied by the moon in travelling from some point in her orbit back to the same point again, on the other hand, is slightly longer than the sidereal month, as the line of apsides of the orbit, or the line passing through the perigee and apogee, revolves round the earth in the same direction as the moon, or from west to east. If, therefore, the perigee be the point from which the period is determined, it will be longer than a sidereal revolution by five and a-half hours; because during the time the moon has made a circuit of her orbit, the perigee has advanced about three degrees. The following are the lengths of the different months:—

	Days.	hrs.	min.	sec.
Mean synodical month (from new moon to new moon), . . .	29	12	44	2·68
Anomalistic month (from perigee to perigee), ...	27	13	18	37·44
Sidereal month (from star to star), ...	27	7	43	11·55
Tropical month (from equinox to equinox), ...	27	9	43	4·68
Nodical month (from node to node), ...	27	5	5	35·81

THE LUNAR ORBIT.

The moon is the nearest of all the heavenly bodies, being situated from us on the average at a distance of about 240,000 miles. As in the case of the planets, the path in which the moon journeys round the earth deviates considerably from a circle. The eccentricity of her orbit amounts, in fact, to about 0·055, or one-twentieth of the semi-major axis. Owing, however, to the perturbing influence of the sun, this quantity is subject to a variation of about 0·01 on either side of the mean value above-mentioned; or the eccentricity alters between the limits of 0·044 and 0·066. The distance of the moon from the earth, therefore, alters to the extent of about 31,000 miles; the maximum distance being 252,948 miles, and the minimum distance 223,593 miles. As already mentioned, the perigee and apogee, or those points in the orbit which are nearest to, and farthest from, the earth, do not always occupy the same position, but move round the ecliptic in an easterly direction. Sometimes, however, they slowly retrograde, but never for a very long period, and therefore the direct movement predominates, advancing at the annual rate of about forty-one degrees, and making a complete revolution of the ecliptic in nearly nine years.

The path in which the moon travels is not situated in the same plane as that of the terrestrial orbit, but is inclined to it at an angle of about five degrees. Like the eccentricity, the inclination is also subject to variation from the altering position of the sun with respect to the earth and moon. Its greatest value amounts to 5 degrees 13 minutes; its least value 5 degrees 3 minutes. Those diametrically opposite parts of the lunar orbit, called the nodes, which cut the ecliptic plane, are not stationary, but move along the ecliptic at the rate of 19 degrees 21 minutes per year. Accordingly, they make a complete circuit of the heavens once every 18·6 years, and in doing so journey in a retrograde direction, or from east to west.

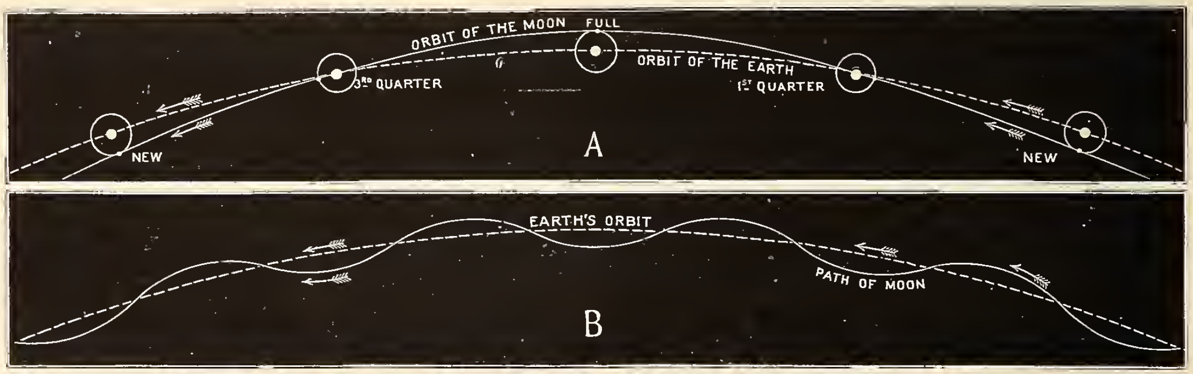


Fig. 19. (*A*) True Path of Moon round the Sun. (*B*) False Path as Formerly Represented.

But the moon moves in another orbit besides the one she describes every month, for while she is revolving round our globe she is also, like our earth, obeying the solar attraction, and, therefore, moves round the sun in a path which differs but little from that traversed by our planet. The annual lunar orbit is slightly elliptical, and strange as it may at first seem, it is always *concave to the sun.* If, for instance, we could watch the movement of the moon from a point in space near the sun, we would notice that our satellite travelled round the centre of the system like any other planet. Sometimes, of course, it would be observed that she was between us and the earth, and occasionally farther away than our globe; but these differences in her distance are so exceedingly small in comparison with the distance of the earth that they could only be detected with difficulty. Fig. 19 is an accurate representation of a small portion of the annual lunar orbit, from which it will be seen that all the effect produced by the monthly movement is, at the time of new moon, to slightly flatten its solar orbit, and at the time of full moon to make it slightly more curved. The moon, therefore, though a satellite of our earth, is also a planet revolving round the sun, and as her average distance from the centre of the system is the same as that of our own globe, her year is equal to ours in length.

DIMENSIONS OF THE LUNAR GLOBE.

Besides being the nearest heavenly body, the moon is the smallest orb that can be seen without telescopic aid. But while this is the case, our satellite is not by any means an insignificant globe. Her diameter is about one-fourth of that of the earth ; or, more exactly, 2163 miles (*see Fig.* 20). The surface of the lunar globe, accordingly, contains nearly 15 millions of square miles, and is less than one-thirteenth of the surface of the earth, or about the same as the combined area of North and South America. Between the *volumes* of the earth and moon there is even a greater difference. The volume of the moon is only one-fiftieth of that of the earth, or it would require fifty globes the same size as the moon to form a globe equal to ours in size. The greatest of all differences, however, is found between the *masses* of the two globes, as the lunar material is not nearly so heavy as the matter forming our earth. The average density of terrestrial material is 5·58 times that of water; the lunar material, on the other hand, is only 3·4 times the density of water. Accordingly a cubit foot of terrestrial matter is heavier than an equal portion of lunar material in the proportion of three and a-half to five and a-half; and, consequently, while it requires fifty globes the same size as the moon to form a sphere equal to that of our earth, it requires no less than eighty moons to make a globe equal to the earth in mass. From this it follows that the attraction of gravity on the lunar surface, or the force with which bodies are drawn downwards will be considerably less than it is here. If the moon were the same size as our globe this force would be exactly one-eightieth of the surface gravity on earth; but as her diameter is over one-fourth of the terrestrial diameter, and as the force increases with the square of the decreasing distance from the centre of the sphere, it is therefore on the lunar surface about one-sixth of the attraction on the surface of our globe.

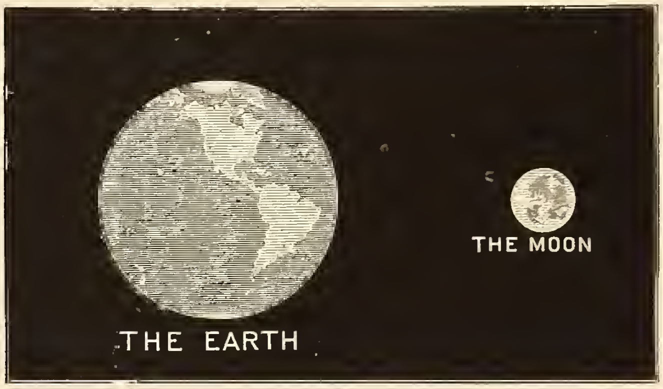


FIG. 20. THE COMPARATIVE SIZES OF THE EARTH AND MOON.

THE ROTATION OF THE MOON.

Like our earth and each of the planets, the moon rotates on her axis, but in a somewhat different manner. In the case of the planets, the rotation periods are not of any great length, and differ greatly from the period of revolution. The lunar rotation, on the other hand, is comparatively long, and curiously enough coincides exactly with the monthly orbital revolution, This is the most remarkable circumstance known about the moon. This fact was discovered shortly after the telescope was invented, as that instrument soon showed that the *same* side of the lunar globe was always directed to the earth. Accordingly but little more than one-half of her entire surface has ever been seen, as the moon presents exactly the same appearance to us as she did to Galileo when first he saw it with his telescope.

The cause of this coincidence of the rotation and revolution periods of the moon is entirely owing to the shape of the lunar globe. In past ages, when the moon was in a molten state, she must have rotated much more rapidly than at present. As her globe cooled, however, the rotation would become gradually slower, owing to the retardative influence of the attraction of the earth. This would, in fact, be sufficient to produce an effect similar to that brought about by the moon on our oceans; for the attraction of our globe would actually raise part of the lunar surface, or create a tide in the soft, and, as yet, hot matter of the lunar globe. This would retard the rotation, and to such an extent, that ultimately it would coincide with the time occupied by the moon in making a complete revolution of her monthly orbit. At the same time, the diameter of the lunar globe, now always directed to the earth, would become slightly more elongated, and, therefore, the moon, instead of being truly spherical, is slightly bulged earthwards.

As might be expected, the movement of the moon on her axis is perfectly uniform. The velocity in her orbit, however, is far from being so, and, consequently, slightly more than a complete half of the lunar globe is seen during an entire circuit. If the moon moved in a circular orbit, her angular movement would be regular, and only the one half of her surface would be visible. But, instead of this, the path of the moon round the earth is very elliptical, and accordingly the lunar movement is faster at perigee and slower at apogee than the mean value. Between these opposite parts of the orbit, the moon's position in her path differs by as much as six degrees from the place she ought to occupy if she had been moving in a circular path, or at her mean angular velocity. At these positions, then, the greatest amount of the invisible hemisphere of the moon will be brought into view, while, on the other hand, near the perigee and apogee, the lunar disc will assume its normal appearance. This apparently alternate swaying of the lunar globe on either side of its mean position is called the *libration in longitude.* But not only are the east and west sides of the lunar disc alternately brought into view, the north and south portions also become visible. This is known as *libration in latitude,* as it depends on the varying position of the moon from the plane of the earth's orbit, or the lunar latitude. The axis of the moon not being perpendicular to the path in which she moves, the north and south poles of her globe are in succession directed towards the earth, and brought into view during a complete revolution.

As the nodes of the lunar equator coincide with those of the orbit, both of the lunar poles are visible at the time the moon is near the nodes of her orbit; while, at the time of the greatest distance from the nodes, the maximum amount of inclination of her axis towards the earth takes place. When at her farthest from the plane of the ecliptic, or at her greatest latitude north, the lunar equator is tilted slightly upwards, and the south pole of the moon is accordingly brought into view. At the greatest southern latitude, the opposite effect takes place, the north pole is visible, and the equator tilted towards us. The amount of apparent swaying thus produced is nearly the same as that of the libration in longitude, or more exactly 6 degrees 44 minutes.

There is still a third libration, one, however, not produced by the moon itself, but by the varying position of the observer on the surface of our globe. When, for instance, the moon is rising, more of the western edge, and, when setting, more of the eastern side is seen than when the moon is on the meridian. This is called *diurnal libration*, which, as mentioned, is the effect of lunar parallax, and, consequently, amounts to slightly over one degree. This phenomenon, as well as the libration in latitude, was discovered by Hevelius, who also first explained the libration in longitude. From the combination of these three librations, considerably more than one-half of the lunar surface is rendered visible. About four-tenths of the surface is always visible, and nearly the same amount is at all times unseen, while nearly two-tenths is alternately visible and invisible.

TELESCOPIC APPEARANCE.

When the lunar disc is viewed with the telescope, it appears to be covered with numerous dark patches. Several of these are so large as to be easily seen with the unaided eye, and when thus viewed near the time of full-moon, they form a likeness to a human face, from which resemblance there doubtless originated the idea of "the man in the moon." Before the telescope was invented, these dark markings, seen on the illuminated lunar disc, were supposed to be seas, as the moon was believed to be a world very much like ours. The telescope, however, soon revealed that this was not the case; for, instead of being a globe like our earth, with large tracts of water on its surface, not the slightest vestige of water or air was visible. The dark parts were, therefore, found to be large level portions of the lunar surface, or extensive plains, and not lunar seas, as had been supposed.

In the chart of the moon at the end of the volume, and also in the photographs at the frontispiece, the size and position which these plains occupy on the lunar surface will be clearly seen. Though the moon is not nearly so large a globe as our earth, these level portions are of considerable dimensions. The *Sea of Serenity,* for instance, which is nearly circular in shape, has an average diameter of 430 miles, and, therefore, has an area equal to that of France; while the *Sea of Crisis,* though smaller than the Sea of Serenity, has an area about equal to that of England and Wales, or covers the one-ninety-fourth part of the visible lunar surface. The general level of the surfaces of these so-called seas is more depressed than the average level of the whole surface of the lunar globe. In fact, the Sea of Crisis is so much depressed that the mountains on its eastern side rise from its surface to a height of about three miles. In long past ages, when water undoubtedly existed on the moon, these lower portions would be completely filled, and are thus nothing more than the bottoms of dried-up lunar oceans. This being the case, it is not difficult to understand how the colour of these plains is somewhat different from other parts of the lunar surface, for vast quantities of dark muddy matter was doubtless carried down by the lunar rivers, and deposited in the once active oceans.

LUNAR MOUNTAINS.

Though not nearly so numerous as on our earth, there are on the moon several ranges of mountains. These, like the terrestrial ranges, run for the most part along the sides of what were at one time the principal oceans. By far the most conspicuous of these ranges is known as the *Apennines,* a chain which extends to a distance of 460 miles along the south-west border of the *Sea of Showers.* The mountain peaks on this range are very numerous, and rise to great heights. In several instances they attain altitudes of no less than three miles. Their heights are determined by the measurements of the long and sharply-defined shadows that are cast from them.

Forming the north-west border of the same sea, and therefore lying at right angles to the *Apennines,* is a smaller chain called the *Alps.* Like the *Apennines,* the *Alps* have their steepest side facing the *Sea of Showers.* In character this beautiful range is exceedingly rugged, its highest peak, *Mount Blanc,* rising to an altitude of about two and a-half miles. Its most striking feature, however, is the gap in it produced by what is known as the Great Alpine Valley, which, dividing the chain near the centre, extends to a distance of about eighty miles. The bottom of this valley when examined under high telescopic powers, is so extraordinarily flat, that it appears more like some engineering work than the production of Nature. This smoothness is evidently the result of long-continued water action, which had the effect of partly wearing down the rugged places, and partly filling up the irregularities with mud and sand; for when the lunar oceans were as active as our own are at present, this valley must have been filled with water, and would then simply be a strait connecting the two seas.

The highest of the mountain peaks in the ranges above-mentioned do not exceed four miles; but these are not by any means the highest mountains of the moon, for several of the lunar mountains attain an altitude of over five miles. Accordingly, the lunar mountains are, in comparison with the diameter of the globe, considerably more elevated than the terrestrial mountains. The highest mountain peak on earth has an altitude above the sea-level of about five and a-half miles, or nearly the same as the highest mountain on the moon. As the diameter of the lunar globe, however, is only one-fourth that of the earth, a distance of five miles on the moon represents about twenty miles on earth; so that it may be said the mountains of the moon are five times more elevated above the level of the lunar plains than those on our globe above the level of the sea.

THE CRATERS.

The numerous white spots indicated in the photographs (*see Frontispiece*) are, for the most part, high ringed mountain peaks, or craters, as they are termed. The most favourable time for viewing these interesting objects is when the terminator, or boundary between the light and dark part, passes near them, because when seen in this position the sun is low down on their horizon, and consequently each elevated portion of the surface casts a long shadow, which has the effect of rendering visible a good deal of detail, impossible to detect on other occasions. The craters are of all sizes, from over 100 miles in diameter down to the smallest objects visible with the most powerful telescopes, or to about one mile in breadth. Their number is exceedingly great, for upwards of 33,000 are indicated on lunar charts. As this, however, only represents about one-half of the entire lunar surface, the actual number on the moon cannot be reckoned less than 100,000.

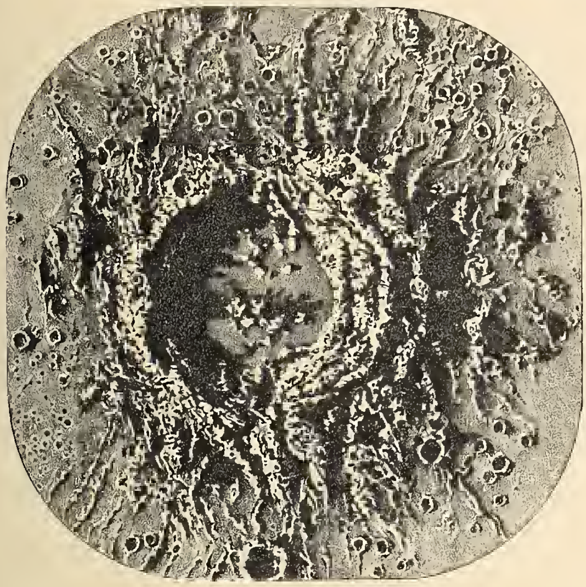
These cup-shaped mountains are divided into two classes—viz., craters with central peaks, and those with flat bottoms, or, as they are called, walled plains. The craters proper are generally very deep, their terraced walls not unfrequently rising from the floor of the crater to a height of over three miles. The walled plains, on the other hand, are comparatively shallow, and, unlike the craters, have very smooth and level floors. One of the finest specimens of a lunar crater is seen near the southern portion of the moon. It is called *Tycho* (*see Plate* 17). The diameter of this magnificent crater is no less than fifty-four miles; while its depth is nearly three miles. In its centre is situated a high conical hill, 6000 feet in altitude. From the character of the surrounding region, one is led to believe that in the days of lunar activity, this large crater was the centre of some of the most tremendous volcanic disturbances which ever convulsed the lunar globe. In addition to thousands of craters of all sizes, there radiates from its base in every direction a wonderful system of bright streaks, some of which are so long that they actually extend to the northern side of the *Sea of Serenity.* These rays are evidently the outcome of some mighty force, generated at a time when the moon was rapidly approaching the solid condition. They are, in fact, believed to be huge cracks produced by the contraction of the surface of the lunar globe, at a time when the matter of the interior had not yet solidified; for, as observation has revealed, the molten substance seems to have flowed out of the rents, thus keeping the surface at nearly the same level, but giving it a different colour.

Copernicus is another gigantic crater, whose diameter amounts to over fifty-six miles, while its terraced walls do not attain a greater altitude than about two miles. The central peak of this grand crater terminates in six points, the highest of which reaches a height of half-a-mile. *Copernicus,* like *Tycho,* is the centre of a bright ray system, but it does not extend to so great a distance as that radiating from *Tycho,* and is probably a much later production.

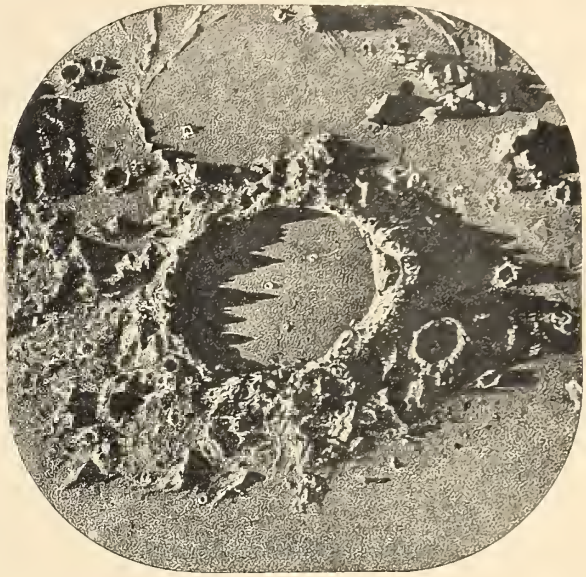
The walled plains were doubtless at one time large craters, whose bottoms have by some means become partly filled up. One of the finest examples of this type of crater is situated at the northern end of the great Alpine range, and known as *Plato.* This plain has a diameter of about sixty miles, while its circular walls vary in height from 1½ to ¾ of a mile. This class of craters is probably the result of volcanic action. As in the case of the ordinary craters, the walls have likely been formed by repeated upheavals of lava and ashes; but, when the force became enfeebled, instead of continuing the ejection of the same material, and gradually building up a conical mountain, as in the case of *Tycho* and *Copernicus,* molten lava seems to have flowed in from beneath, and converted the crater into a smooth plain with greatly elevated walls. The origin of the lunar craters has thus, in all probability, been the same as the craters on earth. The lunar craters, however, are formed on a more gigantic scale, as might be expected from the great difference that exists between the volumes and masses of the two globes. As already mentioned, the force of surface-gravity on the moon is but one-sixth of that of the earth; so that a force which on earth would send a projectile to a distance of a mile, would, on the moon, throw the same object to a distance of six miles. Accordingly, the volcanic force which produced some of the older terrestrial craters, was, on the moon, sufficient to build up a crater with a diameter six times greater, or, in many instances, with a diameter of over sixty miles.

The craters on the lunar surface do not at present show signs of the least activity, as the forces of which they are the outcome have long since ceased. This shows that the moon, though smaller than the earth, is yet older in the scale of development. Being the smaller globe, she would of course cool more rapidly, and reach the solid condition long before our earth. In fact, from its size and composition, the moon must have cooled down in one-sixth of the time occupied by our globe, and is accordingly this amount further advanced in its life's history. If, then, the earth and moon were in the same condition with regard to temper-

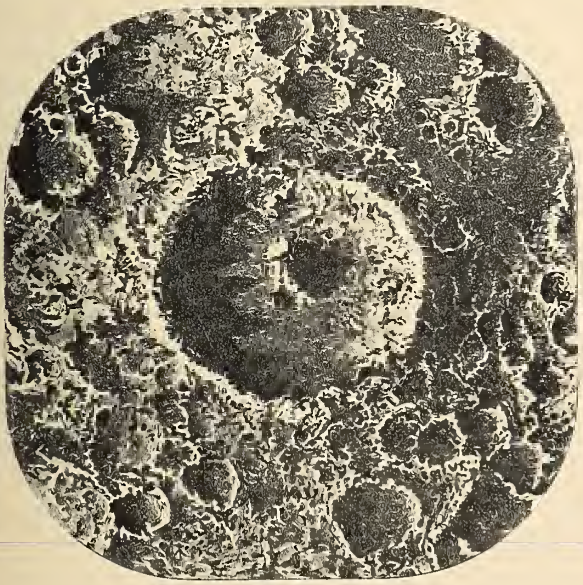
LUNAR CRATERS—PLATE 17.



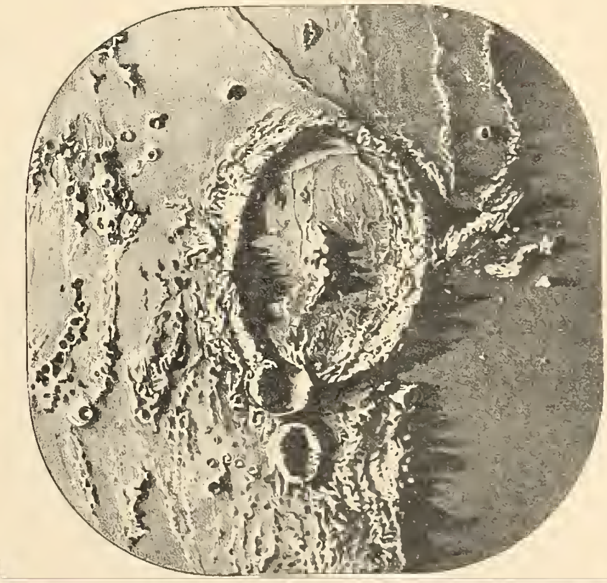
COPERNICUS



PLATO.



TYCHO.



GASSENDI.

[illegible]

DIAMETERS OF THE MORE INTERESTING CRATERS AND WALLED PLAINS.

NAME OF CRATER.	DIAMETER in Miles.	NAME OF CRATER.	DIAMETER in Miles.	NAME OF CRATER.	DIAMETER in Miles.	NAME OF CRATER.	DIAMETER in Miles.	NAME OF CRATER.	DIAMETER in Miles.
Abenezra, .	27.	Campanus, .	30.	Gruemberger, .	39.	Mercator, .	30.	Saussure, . .	28.
Abulfeda, .	39.	Cavendish, .	32.	Halley, . .	21.	Mersenius, .	41.	Scheiner, . .	70.
Agrippa, . .	27.	Cepheus, . .	27.	Hansen, . .	32.	Messier, . .	9.	Schickard, .	150.
Albategnius, .	65.	Clavius, . .	142.	Hansteen, .	31.	Moretus, . .	78.	Schiller, . .	113.
Aliacensis, .	53.	Cleomedes, .	78.	Helicon, . .	13.	Mutus, . .	51.	Schmidt, . .	9.
Almamon, .	36.	Cleostratus, .	150.	Hell, . .	24.	Neander, . .	34.	Schubert, .	46.
Alpetragius, .	27.	Copernicus, .	56.	Hercules, . .	46.	Newton, . .	100.	Scoresby, . .	36.
Alphonsus, .	83.	Delambre, .	32.	Herodotus, .	24.	Nicolai, . .	18.	Segner, . .	46.
Anaxagoras, .	31.	Delisle, . .	16.	Herschel, .	24.	Parrot, . .	42.	Seleucus, . .	32.
Anaximander, .	39.	Deluc, . .	28.	Hevel, . .	70.	Pentland, .	50.	Tacitus, . .	28.
Anaximenes, .	66.	Encke, . .	20.	Hind, . .	17.	Picard, . .	21.	Thebit, . .	32.
Apianus, . .	39.	Endymion, .	78.	Hipparchus, .	92.	Piccolomini, .	57.	Theophilus, .	64.
Arago, . .	19.	Eratosthenes, .	37.	Horrocks, .	18.	Pitiscus, . .	52.	Timocharis, .	23.
Archimedes, .	50.	Eudoxus, . .	50.	Inghirami, .	60.	Plato, . .	60.	Triesnecker, .	14.
Aristarchus, .	28.	Euler, . .	19.	Kepler, . .	22.	Playfair, . .	28.	Tycho, . .	54.
Aristillus, .	34.	Fabricius, .	55.	Lagrange, .	100.	Plinius, . .	32.	Vieta, . .	51.
Aristoteles, .	51.	Fermat, . .	25.	Lalande, . .	14.	Posidonius, .	62.	Vlacq, . .	57.
Arzachel, .	65.	Firmicus, .	39.	Lambert, . .	18.	Ptolemäus, .	115.	Wargentin, .	54.
Atlas, . .	55.	Flamsteed, .	9.	Landsberg, .	28.	Pythagoras, .	95.	Webb, . .	14.
Autolycus, .	23.	Fourier, . .	30.	Lapeyrouse, .	41.	Reiner, . .	21.	Werner, . .	45.
Behaim, . .	65.	Gambart, .	16.	Legendre, .	46.	Reinhold, .	31.	Wilhelm I., .	46.
Blancanus, .	51.	Gassendi, .	55.	Lohrmann, .	28.	Riccioli, . .	106.	Xenophanes, .	185.
Boussingault, .	92.	Gauss, . .	110.	Longomontanus,	90.	Rocca, . .	60.	Zach, . .	46.
Buch, . .	31.	Geber, . .	25.	Macrobius, .	42.	Römer, . .	24.		
Bullialdus, .	38.	Geminus, .	54.	Manilius, . .	25.	Rost, . .	30.		
Burckhardt, .	35.	Grimaldi, .	147.	Manzinus, .	62.	Santbech, .	46.		

LUNAR ELEMENTS.

	d.	h.	m.	s.
Synodical Revolution,	29	12	44	2·684
Sidereal Revolution,	27	7	43	11·545
Tropical Revolution,	27	7	43	4·68
Anomalistic Revolution,	27	13	18	37·44
Nodical Revolution,	27	5	5	35·81

Mean distance from the earth (radius of earth equal to 1),	60·2634
Mean distance in miles,	238,818
Maximum distance in miles,	252,948
Minimum distance in miles,	221,593
Mean angular diameter,	31′ 8″·00
Maximum do.,	33′ 33″·20
Minimum do.,	29′ 23″·65
Actual diameter in miles,	2163·1
Moon's surface in square miles,	14,600,000
Do. do. do. compared with the earth's as 1,	0·0742
Moon's volume ,, ,, ,,	0·02033, or $\frac{1}{49}$
Moon's mass ,, ,, ,,	0·01228, or $\frac{1}{81}$
Density (compared with water as 1),	3·444
Do. (compared with the earth's as 1),	0·604
Surface gravity (,, ,,),	0·165, or $\frac{1}{6}$
Bodies fall in one second of time,	2·65 feet
Mean horizontal equatorial parallax,	0° 57′ 2″·7
Maximum do. do.,	1° 1′ 28″·8
Minimum do. do.,	0° 53′ 51″·5
Mean eccentricity of orbit,	0·054908
Inclination of axis to Ecliptic,	87° 57′ 21″
Inclination of Equator to Ecliptic,	1° 32′ 9″
Mean inclination of axis to Ecliptic,	5° 8′ 0″
Maximum libration in longitude,	7° 45′ 0″
Maximum libration in latitude,	6° 44′ 0″
Maximum diurnal libration,	1° 1′ 29″
Surface of moon never seen,	0·41
Surface of moon seen at one time or another,	0·59
Mean revolution of nodes (retrograde) in years,	18·5997
Mean revolution of perigee (direct) in years,	8·85

ature 100 millions of years ago (a period which is not by any means too long), then the moon would reach our globe's present condition 83 millions of years ago, which informs us that at the time many of the gigantic craters were being formed on the surface of our satellite, the earth was so hot that no terrestrial life whatever could have existed. In like manner, if the moon has taken 100 millions of years to reach her present stage, then she represents the appearance of our globe far in the future—say 500 millions of years hence.

The moon, then, has lived her life as a planet, as there is not at present the slightest sign of water or moisture of any kind. Neither has she now any atmosphere surrounding her, as proved, not only from the blackness and sharpness of the shadows cast by the lunar mountains, but the most delicate tests have been applied again and again without the presence of even the smallest quantity of air being detected. The moon, therefore, cannot be the abode of life—at all events, life similar to that which exists on earth. At one period, however, of her history, vegetable and possibly animal life of some kind may have existed there. Before the telescope was invented, and even after it had revealed the fact that there was no water on her surface, the moon was believed by many to be a miniature of our earth—a globe teeming with countless forms of life. With increase of telescopic power, however, this delusion was dissipated, and the moon accordingly shown to be a lifeless world—a world which truly represents the future of our earth; for, by her present appearance, she points into the future, and tells us that a time shall certainly come when our globe shall be in very much the same condition as herself, when it shall journey round the great centre of the system like the moon at present—viz., a barren and lifeless mass, without air or water on its surface.

CHAPTER VIII.

ECLIPSES.

"The moon
In dim eclipse disastrous twilight sheds
On half the nations, and with fear of change
Perplexes monarchs."—*Milton.*

In the above lines the author of "Paradise Lost" truly expresses the effect produced in superstitious ages by the eclipsing of the two most important heavenly bodies, the sun and moon. When the beautiful "Queen of Night" became darkened and "turned to blood," monarchs were in very deed perplexed, and nations seized with fear. Being it was believed, the effect of Divine wrath, it was thought that nothing short of rigidly performing certain propitiatory acts could prevent the evil that was sure to follow the occurrence of this startling phenomenon. The disappearance of the orb of day, as might be expected, produced even a greater effect on ignorant minds, especially at the time when the sun was worshipped as a deity. History is full of instances of this kind. Nicias, the Athenian general, 400 B.C., was so frightened by an eclipse of the moon that he delayed the retreat of his army from Sicily until it was too late to do so successfully, and from the opportunity thus missed, his army was destroyed, and he himself perished—a misfortune which was the commencement of the downfall of Athens. Columbus, on the other hand, knowing the terror produced on ignorant minds by eclipses, used the prediction of one for the purpose of obtaining food supplies for his soldiers—a historical fact which has been often employed by modern novelists. Being dependent, while in America, on gifts from the Indians for the supply of food, he had on one occasion to give out that he would deprive the world of the moon's light if the supply were stopped. The Indians at first laughed at his announcement, and continued to refuse compliance with his demands; but when the eclipse commenced, they were seized with terror, and soon returned to Columbus, bringing with them the accustomed tribute.*

This great fear and disquietude which eclipses of the sun and moon caused in ignorant and superstitious ages, was beneficial in this respect, they were carefully recorded, and these records laid the foundation for establishing exact science. Posterity was thus enabled to apply to observations those of former generations, and the knowledge thus brought together was the means of ultimately revealing the true nature of the heavenly bodies, and the nature and cause of the celestial motions. At first even the more advanced in thought among the ancients were unable to account for these most startling celestial phenomena, but after numerous generations had observed and recorded, the movements of the two orbs were so far understood, that the occurrence of eclipses could be predicted with approximate accuracy. In fact, centuries before our era, the philosophers of Egypt, Chaldea, and Greece had so carefully studied the motions of the sun and moon as to possess a more accurate knowledge of eclipses than the majority of present-day men of average education. It

---

* This eclipse took place on the 1st of March. 1504—an astronomical fact which has been verified by modern calculations.

SOLAR ECLIPSES TILL 1900.

DATE.			*Nature of Eclipse.*	*LOCALITY WHERE VISIBLE AND CENTRAL.*
1882.	May	17,	Total,	Northern Africa, Arabia, and Central Asia.
„	November	11,	Annular,	Australia and New Zealand.
1883.	May	6,	Total,	Southern Pacific and New Zealand.
„	October	30,	Annular,	Japan and North Pacific.
1884.	April	25,	Partial,	Cape Colony and Southern Atlantic.
„	October	18,	„	Eastern Siberia and Alaska.
1885.	March	16,	Annular,	North Pacific Ocean and Greenland.
„	September	8,	Total,	Australia and New Zealand.
1886.	March	5,	Annular,	Central America and Mexico.
„	August	29,	Total,	Isthmus of Panama to the Congo and Madagascar.
1887.	February	22,	Annular,	Southern Pacific.
„	August	10,	Total,	Russia.
1888.	February	11,	Partial,	The Arctic Regions.
„	July	9,	„	The Antarctic Regions.
„	August	7,	„	(Exceedingly small).
1889.	January	1,	Total,	California.
„	June	28,	Annular,	Madagascar.
„	December	2,	Total,	St. Helena and Central Africa.
1890.	June	17,	Annular,	Southern China to Tunis.
„	December	12,	Total,	Southern Pacific and Australia.
1891.	June	6,	„	Arctic Regions.
„	December	1,	Partial,	(Exceedingly small),
1892.	April	26,	Total,	Antarctic Regions.
„	October	20,	Partial,	(Exceedingly small).
1893.	April	16,	Total,	Brazil.
„	October	9,	Annular,	Central Pacific.
1894.	April	6,	Total,	China.
„	September	29,	„	Sumatra, India, &c.
1895.	March	26,	Partial,	Europe.
„	August	20,	„	Asia.
„	September	29,	Total,	Sumatra.
1896.	February	13,	Annular,	Southern Pacific.
„	August	9,	Total,	Norway and Siberia.
1897.	February	1,	Annular,	South America.
„	July	29,	„	West India Islands.
1898.	January	22,	Total,	Africa, India, China, &c.
„	July	18,	Annular,	Pacific Ocean.
„	December	13,	Partial,	(Exceedingly small).
1899.	January	11,	„	Asia.
„	June	8,	„	Europe.
„	December	3,	Annular,	Antarctic Regions.
1900.	May	28,	Total,	United States and Spain.
„	November	22,	Annular,	Madagascar.

LUNAR ECLIPSES TILL 1900.

DATE.			*Nature of Eclipse.*	*LOCALITY WHERE VISIBLE AND CENTRAL.*
1882.	……		…	No Eclipses.
1883.	April	22,	Partial,	New Zealand and Australia.
,,	October	15,	,,	North and South America and China.
1884.	April	10,	Total,	China and the Pacific Ocean.
,,	October	4,	,,	Europe, Africa, and America.
1885.	March	30,	Partial,	China, Japan, and Australia.
,,	September	24,	,,	Mexico, California, &c.
1886.	……		…	No Eclipses.
1887.	February	8,	Partial,	Sandwich Islands.
,,	August	3,	,,	Madagascar.
1888.	January	28,	Total,	Central Africa.
,,	July	23,	,,	The southern part of South America.
1889.	January	17,	Partial,	Central America and West India Islands.
,,	July	12,	,,	Madagascar.
1890.	June	3,	,,	Pacific Ocean.
,,	November	26,	,,	Pacific Ocean and Philippine Islands.
1891.	May	23,	Total,	Indian Ocean.
,,	November	16,	,,	Soudan and Arabia.
1892.	May	11,	Partial,	Central Africa.
,,	November	4,	Total,	China.
1893.	……		…	No Eclipses.
1894.	March	21,	Partial,	Sandwich Islands.
,,	September	15,	,,	Brazil.
1895.	March	11,	Total,	The northern part of South America.
,,	September	4,	,,	Peru, &c.
1896.	February	28,	Partial,	Arabia.
,,	August	23,	,,	Peru, &c.
1897.	……		…	No Eclipses.
1898.	January	8,	Partial,	Africa.
,,	July	3,	,,	Central Africa.
,,	December	27,	Total,	Northern Africa.
1899.	June	23,	,,	New Guinea.
,,	December	17,	,,	Senegal.
1900.	……		…	No Eclipses.

was from this knowledge that the astrologers of old derived not a little of their power, for being able to give information of their occurrence, astrologers only were considered capable of interpreting the meaning attached to their occurrence.

Though enabled to roughly predict the occurrence of an eclipse, the astronomer of old did not do so from the modern method of calculation, but solely from the discovery he had made, that, with certain modifications, the same eclipse occurred after regular intervals. This remarkable period is called the *Saros*, or Metonic cycle. Its length was found to be eleven days longer than eighteen years. If, therefore, an eclipse occurred, it was known that it would be again seen after that interval. The eclipse, however, might not be again witnessed in the same locality, as the period more accurately consists of 6585·32 days. Accordingly, when the same eclipse once more occurs, it does not take place till one-third of a day, or eight hours, later than the time at which it before happened, and the magnitude of the eclipse is also different. The sun and moon may, therefore, when eclipsed eighteen years afterwards, be beneath the horizon, and the phenomenon be invisible at the place from which it was formerly seen—a consequence which must have greatly increased the difficulty of discovering the Saros, and which gives us an idea of the length of time that doubtless elapsed before it was detected. In this period no less than seventy eclipses usually take place, forty-one of which are solar, and twenty-nine lunar. The Tables on pages 83 and 84 contain the different eclipses occurring in the Saros which ends with the present century.

ECLIPSE SEASONS.

Those who first discovered the Saros would doubtless be unable to account for it, and it was only when the movements of the sun and moon were clearly understood that the cause of eclipses recurring in regular periods became known. The period, in fact, depends entirely on the connection which exists between the motions of the sun, moon, and nodes of the lunar orbit. As mentioned in Chapter VII., the nodes of the moon's path revolve round the ecliptic in a retrograde direction, in an interval of about eighteen and a-half years. This has the effect of shortening the intervals of successive conjunctions between the nodes and the sun and moon. If, therefore, the shadow of the earth be in conjunction with a node, it will be so again after travelling nearly round the heavens, not in a year's interval, as it would be if the node were stationary, but, from its regression, in a period of 346·62 days. This is called an eclipse year, and nineteen of these are equal to 6585·78 days. Now, as we have already seen, the length of a lunation, or the interval between two conjunctions of the sun and moon, is 29·5306 days, which being multiplied by 223 gives 6585·32 days—a difference of only 0·46 of a day. Accordingly, after 223 conjunctions of the moon with the sun, the two orbs will once more be in a line with the nodes, as during the interval the nodes have journeyed nearly round the heavens, and an eclipse will again take place. It will, however, be slightly different in appearance from the former one, when the sun and moon were in the same position, as during the difference between the two periods mentioned above (0·46 of a day, or about 11 hours), the sun has apparently moved about half a degree to the eastward of the node. This has the effect of either increasing or diminishing the magnitude of the eclipse, depending on the movement of the sun whether towards or away from the node respectively. In all cases, however, the eclipse entirely disappears after it has been repeated a certain number of times. In lunar eclipses the repetitions of the same eclipse are performed regularly every 6585·32 days for over 865 years ; and the solar eclipses for 1200 years. At the commencement of the Saros the eclipses of the moon begin as a small partial one, with the sun to the east of the node about twelve degrees. At each successive occurrence the magnitude of the eclipse increases, till after fourteen repetitions the sun generally arrives so near the line of nodes that the eclipse becomes total. As the diameter of the shadow of the earth, where cut by the lunar orbit, is between two and three times greater than the diameter of the lunar disc, it occupies twenty-two repetitions of the Saros before the moon begins to emerge from the shadow, or all of these eclipses are total. By this time the sun has travelled to the west of the node, and before the eclipse fails to appear, thirteen partial occurrences generally take place. The period in which the same solar eclipse is repeated being longer than the lunar one, no less than seventy sometimes occur. Of these, forty-five are visible either as total or annular eclipses, the remaining twenty-five being partial.

From what has already been stated, it will be supposed that it is only when near the nodes that the sun and moon can be eclipsed. This is indeed the case, as at other times the moon is so far above or below the plane in which the earth moves, that an eclipse is impossible. If the moon travelled round our globe in the same level as that in which the sun and earth are situated, the sun and moon would be eclipsed once every month—the former at the time of new moon, by the lunar globe coming exactly between us and the solar disc; the latter at the time of full moon, by the lunar globe passing through the shadow of the earth. The path of the moon, however, as mentioned in Chapter VII., is not thus situated, but inclined to the plane of the earth's orbit, or to the plane of the ecliptic, at an angle of over five degrees. Accordingly, it is only when the moon is within a certain distance from this plane that an eclipse can be produced, so that instead of twenty-five eclipses taking place every year, as there would be if the plane of the lunar orbit coincided with that of the earth, only three or four usually occur.

The sun in his apparent movement round the heavens passes the ascending and descending node at intervals of about six months, and therefore the eclipses in a year occur in two groups, separated by that interval. If the nodes of the lunar orbit were stationary, "the eclipse months" would be exactly half-a-year apart, but as the nodes regress, the period is shortened, being equal to five months and twenty days. The period in which eclipses may occur are, consequently, earlier every year by double the difference of ten days from six months, or by twenty days. The number of eclipses occurring in an eclipse season depends on the manner in which the conjunction with the node takes place. If, for example, the new moon took place when the lunar globe was exactly at a node, a central eclipse of the sun would be the result; while half-a-month before and after this event, at the time of full moon, the moon, though being near the opposite node, would yet be sufficiently distant from it as to escape being eclipsed. Under such circumstances only one solar eclipse would take place — the minimum number in an eclipse season. If, on the other hand, the moon should be exactly in the node at the time of opposition to the sun, or at full moon, a central lunar eclipse would be produced; and half a lunation later or earlier, at the times of the preceding and following new moons, the lunar globe would be within sufficient distance of the node to partially eclipse the sun. This is the greatest number of eclipses that can occur in an eclipse season—viz., two solar and one lunar. The maximum number of eclipses occurring in a year is six, two of which are lunar, and four solar. Occasionally there may be seven eclipses, but usually the number does not exceed four or five.

Although generally the solar eclipses exceed in number those of the moon in the proportion of three to two, yet from a given point on the earth's surface more lunar eclipses than solar are seen. This is owing to the fact that solar eclipses are only visible from very limited portions of our globe, while eclipses of the moon, which do not depend on the lunar parallax, can be seen over considerably more than a complete hemisphere; so that the proportion of lunar and solar eclipses witnessed from a *given place* is more than reversed. Eclipses of the sun and moon are of great use in chronology, as by them many distant dates have been accurately recovered. Ptolemy records many eclipses, and gives the reigning monarch at the place where observed, from which, by verification, a number of valuable points in Egyptian, Babylonian, and Grecian chronology have with precision been established.

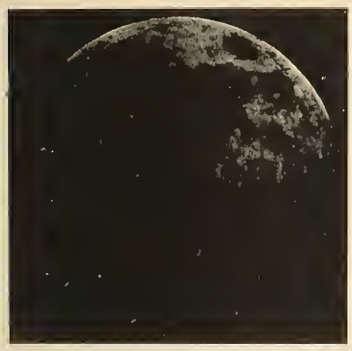
ECLIPSES OF THE MOON.

From what has been stated it will be seen that it is only at the time of full moon, and when the luna globe is then within a certain distance from one of its nodes, that the moon can be immersed in the shadow of the earth, and become obscured or eclipsed. This distance is not always the same, as it obviously depends on the inclination of the lunar orbit, and the breadth of the earth's shadow, both of which are subject to variation. As already mentioned, the inclination of the moon's path to the plane of the ecliptic varies from 5 degrees 13 minutes to 5 degrees 3 minutes. The breadth of the shadow cone where cut by the lunar orbit

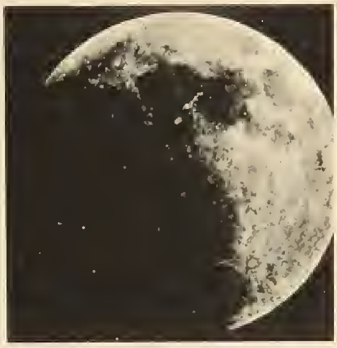
THE
TOTAL LUNAR ECLIPSE
OF JANUARY 28TH, 1888,

As Photographed at Murrayfield Observatory by W. Peck, F.R.A.S.,
with Silver-on Glass Reflecting Telescope of 13 inches aperture.

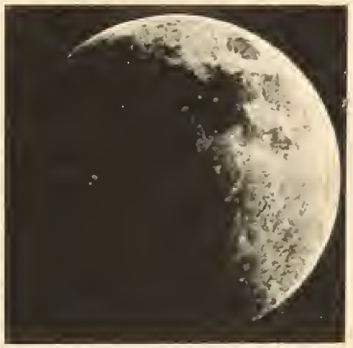
THE FOLLOWING ARE ACCORDING TO GREENWICH TIME:—



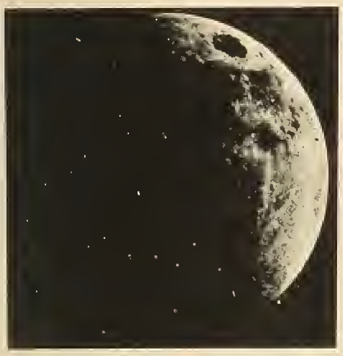
9H. 32M. 0S.



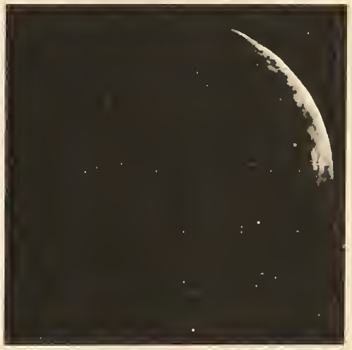
9H. 37M. 40S.



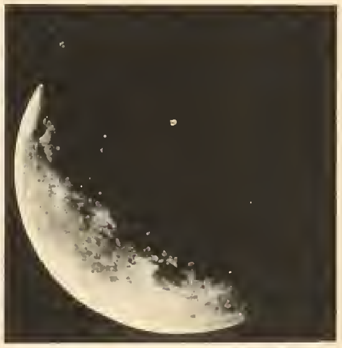
9H. 45M. 20S.



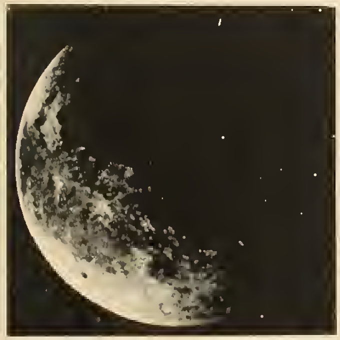
10H. 0M. 20S.



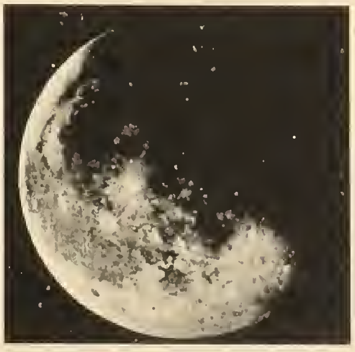
10H. 15M. 5S.



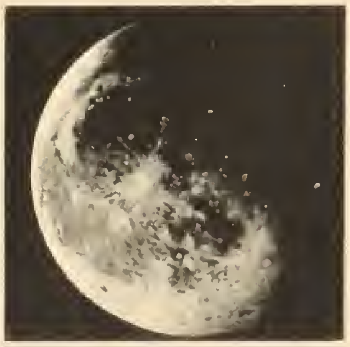
12H. 36M. 37S.



12H. 47M. 20S.



13H. 1M. 38S.



13H. 7M. 20S.

alters to even a greater extent, as it depends not only on the varying distance of the earth from the sun, but also on the varying distance of the moon from the earth. From these causes the distance of the moon from the node in order to be eclipsed, or the " lunar ecliptic limits " as it is called, alters from 12 degrees 5 minutes to 9 degrees 30 minutes. If, therefore, the moon be within the greater of these limits from one of the nodes at the time of full moon, it may be eclipsed, and if nearer the node than the smaller limit it will certainly come into contact with the earth's shadow. As the sun apparently journeys round the star-sphere at the average velocity of about one degree per day, it follows that an eclipse of the moon cannot take place if the full moon occurs more than thirteen days before or after the time of the sun's conjunction with the node.

When in January the earth is nearest to the sun, the shadow is shortest, and when in the opposite part of her orbit, in July, it is longest; while midway between these positions it extends from our globe to the average distance of 857,000 miles. Accordingly, if the moon revolved round our globe in a circular path, the duration of the eclipse, which depends on the breadth of the shadow cone, would vary with the season of the year. But the moon, as we have seen, travels in an orbit which is elliptical, and, consequently, her distance from our globe alters to a considerable extent. Owing to this variation of distance, the breadth of the shadow, where traversed by the moon when totally and centrally eclipsed, is sometimes as much as three times the diameter of the lunar globe, and at other times scarcely more than twice its size. In calculating lunar eclipses, astronomers do not compute the breadth of the shadow in miles, but its apparent angular breadth as viewed from the earth. The following are the different diameters of the terrestrial shadow, at the place where it is cut by the lunar orbit, or the angle C D, Fig. 1, Plate 18, for various positions of the sun and moon :—

APPARENT DIAMETER OF THE EARTH'S SHADOW IN LUNAR ECLIPSES.

POSITION OF SUN.	*POSITION OF MOON.*	*APPARENT DIAMETER OF SHADOW.*
Nearest to the earth,	Farthest from the earth,	1° 15′ 24″
,, ,,	At mean distance from the earth,	1° 23′ 2″
,, ,,	Nearest to the earth,	1° 30′ 40″
At mean distance from the earth,	Farthest from the earth,	1° 15′ 58″
,, ,, ,,	At mean distance from the earth,	1° 23′ 35″
,, ,, ,,	Nearest to the earth,	1° 31′ 13″
Farthest from the earth,	Farthest from the earth,	1° 16′ 28″
,, ,,	At mean distance from the earth,	1° 24′ 6″
,, ,,	Nearest to the earth,	1° 31′ 44″

In consequence of this variation in the breadth of the terrestrial shadow, at the place where traversed by the moon, the duration of total central eclipses is of different lengths. The greatest period of totality lasts about two hours, and as the moon moves over her own diameter in an hour, the whole interval, from first to last contact, is thus about four hours. The length of a partial lunar eclipse depends, of course, on the distance of the moon from the node, it being least when near the ecliptic limit.

When the moon has been wholly immersed in the shadow of the earth, she is not, as one might suppose, invisible, but generally shines with a dull, copper-coloured light. This visibility is caused by the atmosphere of the earth refracting the solar rays into the dark shadow, and faintly illuminating the lunar disc. The blood-red colour that the moon sometimes assumes is the outcome of the effect which the lower portion of the atmosphere has on the light rays, for by it the blue rays are absorbed, and the red only pass through. As the horizontal refraction amounts to over half-a-degree, and as the diameter of the terrestrial shadow is more than one degree, the moon is thus, even when in the centre of the shadow, slightly illuminated (*see Plate* 18). There are instances, however, of the moon completely disappearing during the total phase, these having been brought about by dense clouds in the terrestrial atmosphere. The appearance of the lunar disc when immersed in the shadow of the earth is, therefore, an index of the condition of our atmosphere at those places on the edges of the earth's disc through which the light is passing at the time. If, for instance, the moon appears bright, the sky is clear and the weather fine at those places where the sun is rising and setting; if, on the other hand, she is scarcely visible, or entirely disappears, the weather is stormy.

In Fig. 1, Plate 18, a faint shadow, or *penumbra* as it is called, is indicated. This, however, cannot be seen on the moon, though the time of the lunar globe in entering and leaving it is always given in the almanac. Within the penumbra lines indicated in the Plate, the moon is only partially illuminated by the sun, as, until the moon has travelled outside of the penumbra, part of the solar disc, as seen from the moon, is hidden by the earth. But even when nearly all of the sun is cut off by the earth at the time when the lunar disc is either about to enter or leave the umbra, or dark shadow, the moon appears to shine with her usual brightness, owing to the great contrast between the nearly total obscuration, when immersed in the shadow, and the partial illumination from the sun's direct rays.

ECLIPSES OF THE SUN.

As already mentioned, the sun is always eclipsed when the moon is in conjunction with him at the time she is within a certain distance from either of the nodes of her path. This distance from a node within which the sun is eclipsed, is termed the "solar ecliptic limits." These are larger than the lunar limits, because the parallax of the moon has the effect of increasing them to a considerable extent. If viewed from the centre of the earth, for instance, the sun would often be entirely free from the lunar disc, while from certain parts of the surface of our globe, the moon, from the effect of parallax, may be so much depressed or raised, that an eclipse of considerable magnitude will be seen. The major solar ecliptic limit is accordingly as great as 18 degrees 31 minutes, within which distance from a node, the moon, in passing the sun, *may* produce an eclipse. The minor limit is 15 degrees 21 minutes, within which distance from a node, the moon, in coming into conjunction, will certainly eclipse the sun. But, while under these conditions a solar eclipse of some kind will be produced, it may not necessarily be a central eclipse. In order to insure that the moon will be seen from some part of our globe centrally projected on the sun, she must be nearer to the node than the distances above stated. Before a central solar eclipse can be produced, the moon must, in fact, be within about 10 degrees of the node of her orbit at the time of conjunction with the sun.

Owing to the variation of the moon's distance from the earth and sun, the length of the lunar shadow is not always the same. It alters in the proportion of about 87 to 84, or, in actual miles, from 236,000 to 228,000. As this latter distance is less than the moon's distance from the earth, it follows that sometimes the lunar shadow does not touch the surface of our globe at all, but falls short of it by a considerable distance. The different distances of the vertex of the lunar shadow from the earth for various positions of the moon and sun are given on the Table on page 89.

It is only in those cases where the length of the lunar shadow is greater than the distance of our satellite from the earth that the sun can be totally eclipsed. On all other occasions, when the shadow is shorter than the distance of the moon, the eclipse, though central, is not total. The diameter of the lunar disc is then slightly smaller than that of the sun, and consequently the solar disc is not completely hidden, but appears as a ring of light surrounding the dark globe of the moon. This is called an annular eclipse of the sun, and, as might be expected, this phase occurs more frequently than the total one; they do so, in fact, in the proportion of about three to two.

In the case of total eclipses, the breadth of the shadow cone, where it falls on the surface of the earth, is not very great, being under the most favourable conditions only 167 miles in diameter (*see Plate* 18). This

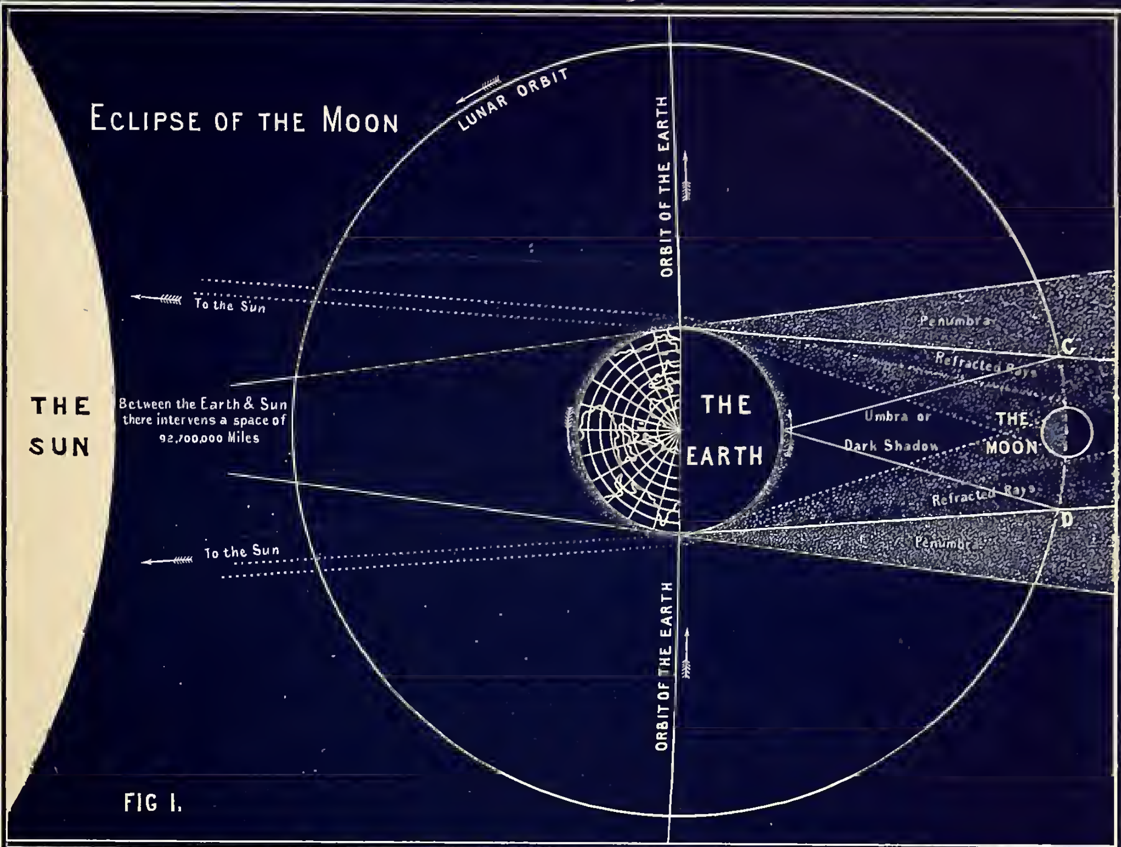

ECLIPSE OF THE MOON
LUNAR ORBIT
ORBIT OF THE EARTH
To the Sun
THE SUN
Between the Earth & Sun there intervens a space of 92,700,000 Miles
Penumbra
Refracted Rays
C
THE EARTH
Umbra or Dark Shadow
THE MOON
Refracted Rays
D
Penumbra
To the Sun
ORBIT OF THE EARTH

FIG I.

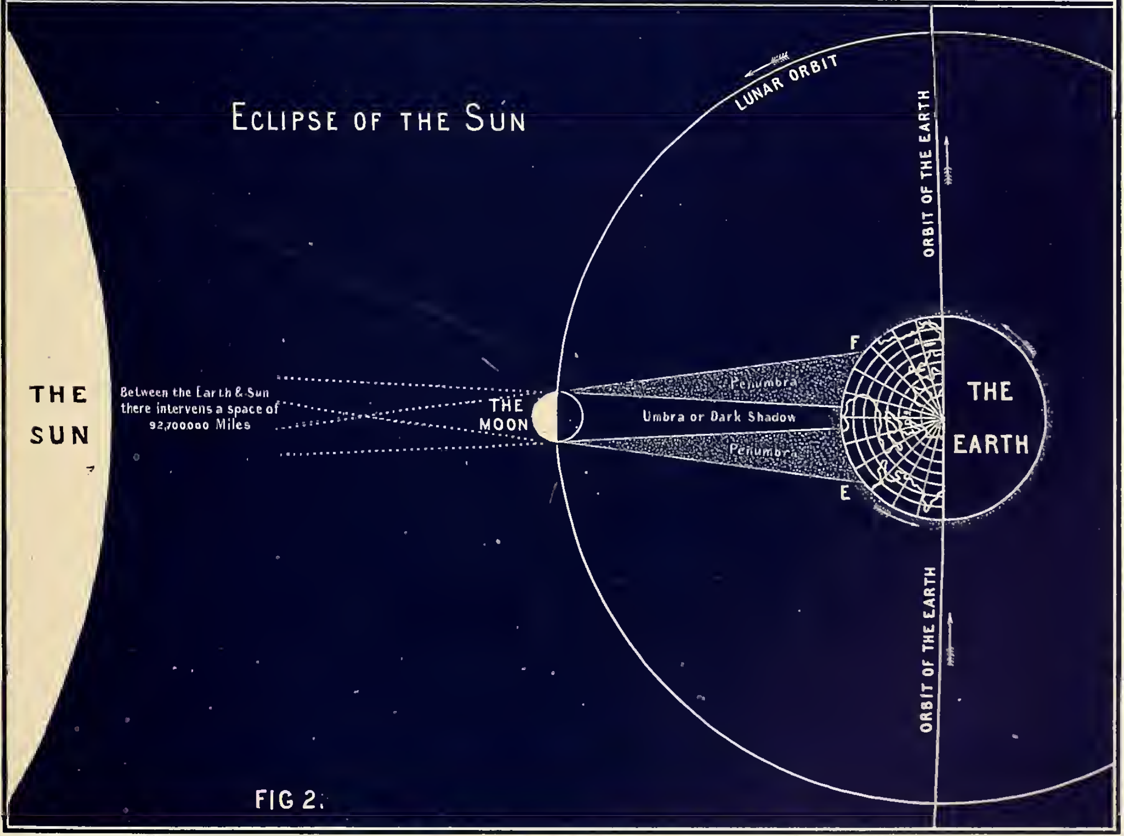

ECLIPSE OF THE SUN
LUNAR ORBIT
ORBIT OF THE EARTH
THE SUN
Between the Earth & Sun there intervens a space of 92,700000 Miles
THE MOON
Penumbra
Umbra or Dark Shadow
Penumbra
F
E
THE EARTH
ORBIT OF THE EARTH

FIG 2.

Constructed by W. Peck Edinburgh

shadow spot, however, travels over the surface of our globe at a considerable velocity, and consequently the total phase is not confined to so limited a region, but may be seen at places differing from each other by distances often amounting to thousands of miles. If the earth had no rotation, and the moon were situated on the equator, the velocity of the shadow over the terrestrial surface would be the same as that of the moon in her orbit—viz., 2100 miles an hour. The earth, however, is rotating in the same direction as that in which the moon travels in her orbit, and therefore the movement of the shadow is retarded by the rotation velocity of the place on which the shadow falls. Accordingly, when the shadow of the moon falls on the equatorial regions of our globe, it journeys at the velocity of 1060 miles an hour.* This is its slowest speed, as places near the equator are carried eastward by the rotation of the earth at the maximum velocity, or about 1040 miles an hour, yet it is equal to the speed of a cannon ball. As the locality at which the total eclipse is visible increases in distance from the equator, the speed of the shadow becomes greater, until the shadow falls beyond the pole. The rotation velocity of the place then being in the same direction as the movement of the shadow, it becomes added to it, and the speed of the shadow is at a maximum.

Along with this variation of the velocity of the lunar shadow in traversing the surface of our globe, the duration of the total phase also varies with the place of observation. As the movement of the moon in her orbit is apparently most retarded near the equator, the length of the total phase is there longest. It is not, however, of long duration, for under the most favourable conditions it only lasts 7 minutes 58 seconds. As the latitude of the place increases the duration of total phase becomes less; at the latitude of London it is not greater than 6 minutes. Annular eclipses, as already mentioned, take place when the lunar shadow fails to reach the surface of the earth. They are, therefore, greatest, or the ring of light broadest, when the sun is nearest the earth and the moon in apogee; under these conditions the apparent diameter of the sun is at a maximum, and the lunar disc smallest. Then also the moon moves at her least velocity, and consequently the duration of the annular phase is greatest; at the equator it is 12 minutes 24 seconds, and at the latitude of London a little less than 10 minutes.

DISTANCES OF VERTEX OF LUNAR SHADOW FROM THE EARTH IN SOLAR ECLIPSES.

POSITION OF SUN.	*POSITION OF MOON.*	*POSITION OF VERTEX OF SHADOW.*
Nearest to the earth . .	In apogee, ...	23,000 miles in front of the earth.
,, . .	At mean distance, . .	9,000 ,, from the earth.
,, . .	In perigee, ...	8,000 ,, behind ,,
Farthest from the earth .	In apogee, ...	16,000 ,, from the earth.
,, . .	At mean distance, . .	2,000 ,, ,, ,,
,, . .	In perigee, ...	16,000 ,, beyond ,,

From all places lying within a certain distance to the north or south of the line where the sun is centrally eclipsed, a portion only of the solar disc is obscured. This distance on the surface of the earth from the line of central phase is determined by the penumbral lines E F (*Fig.* 2, *Plate* 18). Within these the sun is partially eclipsed, the amount of obscuration increasing with the approach to the line of central phase. On some occasions the penumbral lines are no less than 4400 miles apart, so that while total and annular eclipses can only be seen within very narrow limits, the same eclipse will be visible as a partial one everywhere within 2000, and sometimes 3000 miles of the shadow path.

---

* =2100 miles (velocity of moon in orbit) − 1040 (rotation speed of equator) = 1060.

CHAPTER IX.

ASTRONOMICAL INSTRUMENTS.

"Here truths sublime, and sacred science charm,
Creative arts new faculties supply,
Mechanic powers give more than giant's arm,
And piercing optics more than eagle's eye."—*Beattie.*

INSTRUMENTS OF THE ANCIENTS.

As soon as primitive man began to take notice of the various celestial phenomena continually occurring, he would endeavour to find out how such remarkable appearances were caused. In order to do this successfully, he would soon discover that it was necessary to constantly observe how the different heavenly bodies moved. Hence would arise the necessity for employing some kind of instrument, and such an instrument Nature supplied to him when dwelling on the level plains of eastern countries, by giving him a clear and regular horizon. This was probably the first astronomical instrument. By it the rising and setting of the various orbs would, with tolerable accuracy, be determined, and also their apparent distances from each other indicated. Combined with these horizontal observations, records of eclipses, and conjunctions of the planets with the brighter stars lying near their paths, and with each other, would be carefully made. The Egyptians, Chaldeans, and Chinese made thousands of such observations hundreds of years before our era, and by means of them discovered so important a period as the Saros. From these observations, too, it would be found that some kind of instrument was necessary for determining the position of the heavenly body when above the horizon, and this want would lead to the invention of the first angular instrument—viz., the gnomon.

The sun, moon, and stars, it would be noticed, after appearing above the horizon, would mount into the sky, gradually increasing their altitude, till reaching a certain height, when they would begin slowly to fall and approach the horizon again towards the west. The points in the sky where the various orbs attained their highest altitude would soon be discovered to be all situated on a single line—a line which accurately divided the diurnal course of each orb into halves. Accordingly, the position which the different bodies occupied when on this line, now known as the meridian, would be considered as important, and means would be required to obtain the information. In the case of the sun and moon, this was easily done by determining the lengths of the shadows cast by these luminaries, and, consequently, for many generations the altitudes of the stars could not be measured. The first astronomical instrument might simply be an erect staff, whose height was known. The invention of the gnomon is attributed by Herodotus to the Babylonians; but it was also employed by the Egyptians, Chinese, and Indians. Doubtless the numerous obelisks which have been erected in eastern countries were originally put up to serve as gnomons, and even the Pyramid may, at first, have been a more advanced kind of instrument for determining both the horizontal and meridional positions of heavenly bodies..

From the length of the shadow cast by the gnomon the solar and lunar altitudes were determined, and, from the equal lengths of the shadow at equal distances from the meridian, the exact direction of that line, and the time of the passage of those luminaries across it, were known with approximate accuracy. By observing the gradual increase or decrease of the meridional shadow from day to day, the times when it was longest and shortest became known. These occasions, which were called *solstices* because the sun was then found to remain for several days at nearly the same altitude, were noticed to occur regularly at certain intervals, and by this means the length of the solar year was first approximately known. From the use of the gnomon, also, the inclination of the path in which the sun apparently moves round the star-sphere to the equator was measured. By such means, the Chinese, 2000 years before our era, found that this inclination, or the obliquity of the ecliptic, as it is now termed, was twenty-three degrees thirty-eight minutes (*see The Earth, Chapter V.*).

Very often the gnomon was constructed of great length, in order to insure accuracy of observation, yet notwithstanding this, the results were somewhat inaccurate. The sun, not being a luminous point, but a disc of some size, the shadow projected from the end of the gnomon is not sharply defined, but gradually fades away. Accordingly, the length of the shadow was not known with certainty, and the greater the gnomon's height the greater the difficulty in determining the extremity of the shadow. To obviate this defect, the gnomon was sometimes terminated with a disc of metal, pierced with a small hole. This cast an elliptical shadow on the ground, with a central luminous spot, the centre of which gave, more accurately than the ordinary gnomon, the height of the sun's centre. In comparatively modern times this simple astronomical instrument was not altogether unused, for in the year 1467 a gnomon 277 feet high was erected at Florence, and about the same time one 80 feet in height was erected at Paris.

Another very ancient instrument for determining the height of the sun was the hemisphere of Berosus, which consisted of a hollow hemisphere, with a horizontal rim, with a style placed in its centre. This instrument was an advance on the gnomon, and it doubtless led to the invention of circular instruments generally. The altitudes of the sun and moon were determined directly by observing the division on which the extremity of the shadow fell; and this hemisphere was also employed in dividing the day into equal parts.

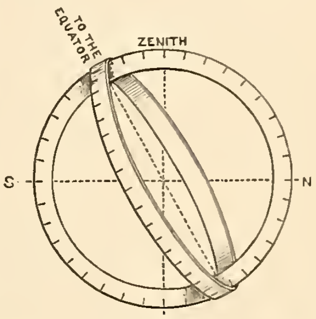


FIG. 21. THE MERIDIAN INSTRUMENT OF ERATOSTHENES.

We now come to the use of circular instruments properly so called. As far as is known, the Alexandrian astronomers under Eratosthenes were the first to employ the circle in making observations, but doubtless it had been used long before his time. The observatory at Alexandria had been established at least 300 years B.C., and many valuable observations had been made there by the two celebrated philosophers, Aristillus and Timocharis. After these came Aristarchus, who must have employed circular instruments of some kind, as his observations did much to extend the knowledge of the heavenly bodies. Eratosthenes, however, has the honour of inventing the first meridian instrument, which consisted of two circles of nearly the same size, and crossing each other at right angles (*see Fig.* 21). The circle S N was placed in the meridian, or exactly north and south, and in such a position that the other circle was tilted upwards, so as to point to the celestial equator. By this means the altitude of the sun when on the meridian could be conveniently observed, and the exact time of the sun crossing the equator, or the instant of the equinox, determined.

As mentioned in Chapter I., the division of the circle into 360 equal parts doubtless originated from the rude discovery that the great circle of the heavens, as marked out by the sun's apparent yearly course, consisted of 360 spaces, each of which was traversed by the sun in the interval of a day. This supposition is borne out by the fact that the old solar year contained only 360 days. Hipparchus, about 160 B.C., employed such a division of the circle, and invented many instruments and methods of observations on a basis so sure, that for several generations they were not surpassed.

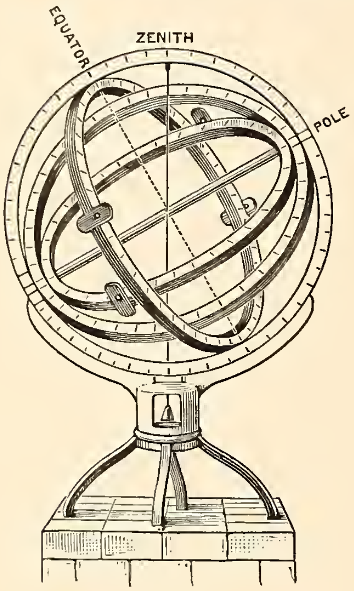


Fig. 22. THE EQUATORIAL ASTROLABE.

One of the most important of his inventions was the celebrated astrolabe (*Figs.* 22 *and* 23). This consisted of a meridional circle, and several interior circles which could move about an axis. One of these, as in the instrument of Eratosthenes, was directed towards the equator, while the others, swinging about an axis which pointed to the poles of the heavens, were used to determine the distances of the various celestial objects from that great circle of the celestial sphere. Unlike the instruments hitherto employed, the object did not require to be on the meridian in order to find this position, but its equatorial distance, or declination as we now call it, could be measured during any time it remained above the horizon. To determine the position of a heavenly body with respect to the ecliptic or sun's apparent annual path, a similar instrument was devised, only the axis round which the circles moved, instead of being fixed, as on the last-mentioned instrument, had itself a movement round a second axis. This was to enable the observer to make the principal axis coincide with the poles of the ecliptic, or those points which are perpendicular to the annual path of the sun. As the position of these points with respect to the horizon, owing to the diurnal rotation of our globe, is constantly altering, the axis of the instrument would thus require to be adjusted for every observation. By means of the second axis this could easily be done, when the distance of the particular object from the ecliptic could be measured. In this way the first accurate star catalogue was made by Hipparchus, who determined the positions of over 1000 stars with remarkable accuracy. It was by this means that the important discovery of the precession of the equinoxes was made; for by comparison of his own positions of the stars with those made by Aristillus, Hipparchus found that the stars were apparently travelling along the ecliptic in an easterly direction, or the equinoctial points were moving in the opposite direction, to the west (*see Chapter II.*).

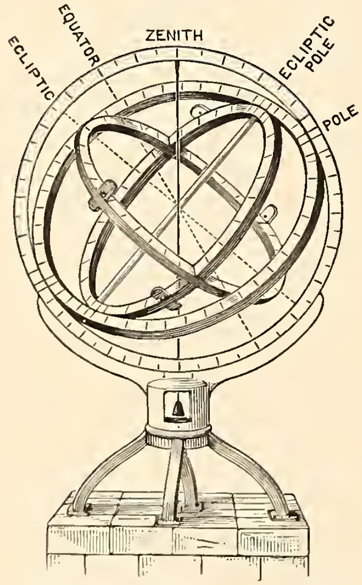


Fig. 23. THE ECLIPTIC ASTROLABE.

The next celebrated astronomer after Hipparchus was the so-called "Prince of Astronomers," Ptolemy, who made observations at Alexandria about the year 150 A.D. He principally employed the instruments invented by Hipparchus, but also used another which he specially describes—viz., the Parallactic Rules. This instrument is believed to have received its name from being employed in determining the parallax of the moon. It consisted of three long rods, one of which had divisions on it, whereby the angle of the summit of the instrument was found, which was equal to the zenith distance of the object (*Fig.* 24). This type of instrument was used by astronomers as late as the fifteenth and beginning of the sixteenth centuries—a fact which shows that it must have been considered capable of measuring angles with considerable accuracy.

Up to this time astronomers could not meet one very great want. They could not, even with approximate accuracy, by mechanical means determine time. Of course, if the sun were above the horizon, the time was easily found by means of the sun-dial, but if the sky were cloudy, or during the night, the time was not known with certainty, as the mechanical apparatus for indicating time was very defective.

The principal instrument used for this purpose was the clepsydra, or water-clock, which was simply a vessel of a particular shape with a small aperture at the bottom through which the water flowed, the time being indicated by the height of the water in the vessel, or by the amount which flowed out. The invention of this ingenious instrument is attributed to the Egyptians; but as it could not be relied on for astronomical observations, it was not much employed by astronomers. Ptolemy entirely rejected it, and for his more important observations accurately fixed the time by measuring the altitude of the sun during the day, and during the night by making a similar use of some bright star.

INSTRUMENTS USED BEFORE THE INVENTION OF THE TELESCOPE.

From the time of Ptolemy to the beginning of the sixteenth century, little improvement was made in astronomical instruments. Till then the best observations had been made in the east, principally by the Arabians and Persians. In the country of the latter, towards the end of the thirteenth century, a magnificent observatory was erected, the remains of which were discovered in the year 1830. According to the best Mohammedan writers, this observatory contained an apparatus for representing the celestial sphere, the signs of the zodiac, the conjunctions, transits, and revolutions of the different heavenly bodies. Through an aperture in the dome, the solar rays were transmitted, and by falling upon certain lines on the paved floor indicated the altitude and declination of the sun, and the hour of the day.

Instrumental astronomy in the east reached its height towards the middle of the fifteenth century. About the year 1430, the Tartar prince, Ulugh Begh, established at his capital, Samarcand, an academy of astronomers, and erected for their use the most magnificent and costly instruments. Among these was a gnomon 180 feet in height, by means of which the obliquity of the ecliptic was determined to be 20 degrees 30 minutes, the precession of the equinoxes 1 degree in 70 years, and the various elements for the construction of tables, which have been proved to rival in accuracy those of Tycho. Hitherto only one star catalogue had been constructed—viz., that of Hipparchus; Ulugh Begh, however, constructed another, and accordingly had the honour of producing the second, after an interval of sixteen centuries.

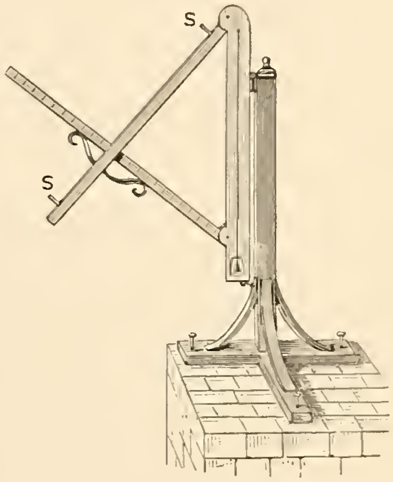


FIG. 24. THE PARALLACTIC RULES.

With the death of Ulugh Begh commenced the decline of astronomy in the east. It was beginning, however, to be cultivated among races which were capable of developing the intellectual powers to their fullest extent. Europe had by this time awakened from the lethargy in which it had been enveloped for so many ages, and astronomy, among other sciences, began to be cultivated with marked success. It was in this condition when Copernicus greatly stimulated the study by totally renovating the science. This he accomplished by overthrowing the Ptolemaic system, which had for so many centuries held sway, and advancing one of his own, which in after times was proved by repeated observations to be accurate. These observations were furnished by the celebrated Danish nobleman Tycho Brahé, a believer in the older systems, who afterwards invented a system of his own, wherein the earth was still considered to be the centre of the universe. Tycho was an indefatigable and skilful observer, and as such was considered to be vastly superior to any who had preceded him since the revival of astronomy in Europe. What Hipparchus, the so-called father of astronomy, had been to the science of the ancients, Tycho was, to as great an extent, to the science of the middle ages. His observatory, which was erected at Huen in the year 1576, was a magnificent building, and was considered to be next in importance to the one established at Alexandria under the Ptolemies. The principal part of this observatory, which Tycho called Uraniberg, or the city of the heavens, consisted of a building sixty feet square, with towers to the north and south, containing also a museum and library. The collection of instruments at this observatory was the largest and finest which had ever been made. At first the principal ones employed were similar to those invented and used by Hipparchus, except that they were larger and of more accurate construction.

One of the chief instruments used by Tycho was the equatorial astrolabe, already described as having been invented by Hipparchus. With this apparatus Tycho was enabled to determine with far greater accuracy than had hitherto been done, the declinations and right ascensions of 1500 stars, and this, too, without the aid of a clock. One of these instruments was of a very large size, having a circle over seven cubits in diameter, which (taking the cubit as eighteen inches in length) is about eleven feet, and was, therefore, probably more accurate than the smaller instruments he possessed of the same kind. Another noted instrument was a mural quadrant, five cubits in diameter, very minutely graduated; also a moveable one, by means of which the altitude and azimuth of an object could by one observation be determined with great accuracy. Another very important instrument employed at Uraniberg, and invented by Tycho,was one which only contained a portion of a circle, called the sextant. This instrument was greatly used in measuring the angular distance of two heavenly bodies from each other, in particular, of the moon from a star. By means of his numerous instruments Tycho was able to fix the position of any celestial object to within about fifteen seconds of arc, a considerable advance on the observations of Hipparchus, as these latter were not certain to within less than ten minutes; and it was from the accumulation of the numerous observations thus accurately made, that his disciple, Kepler, was supplied with materials by which he may be said to have constructed the true system of the universe.

THE INVENTION OF THE TELESCOPE.

The telescope is undoubtedly the most important of all astronomical instruments, giving, it may be said, a new sense to the human race, whereby many of Nature's greatest mysteries have been revealed. Like several other important inventions the origin of the "optic tube" is lost in obscurity, and like many of them also, it was rather the outcome of a particular age than of an individual mind. For some time previous to the commencement of the fourteenth century lenses were in common use for perfecting vision, a fact which leads one to believe that a combination of two or more of them would be made during the long interval that elapsed between the knowledge of lenses and the time which has been assigned to the invention of the telescope proper —viz., near the middle of the seventeenth century.

The exact date at which the telescope was invented is not known with certainty. Galileo knew absolutely nothing about it till the year 1609, but it is certain that its use was known in Northern Europe some time prior to this date. It was only through information casually received that Galileo learned there was such an instrument, and, though unable to see one, he soon discovered the principle on which it was constructed. By a combination of a large convex and small concave lens fitted into a leaden tube, he contrived an instrument which was capable of giving a distinct view of distant objects. The first instrument constructed on this principle magnified only *three* times, but it was soon superseded by another which magnified *eight* times. The success of these instruments encouraged Galileo to attempt the construction of a larger one, in which he was entirely successful, for a telescope was produced magnifying no less than thirty times. By means of this instrument, one which was not nearly so perfect as a modern pocket telescope, the science of astronomy was greatly advanced. Numerous discoveries were soon made with it. Mountains were noticed in the moon, and spots on the sun; VENUS was found to have phases, thus proving the truth of the Copernican theory; JUPITER to have satellites; SATURN to have a strange appendage; and the Milky Way to be composed of myriads of stars.

In this form of instrument, which is still used as the opera-glass, the rays, as will be noticed from (*a*) Fig. 25, pass through the concave eye-glass before they reach the focus of the large convex lens, where the image of the distant object is formed. The Galilean telescope has never been constructed of large dimensions, as it is a very defective instrument for astronomical purposes, owing to the smallness of the field of view and its unsuitability for measuring the position of objects.

It was not till after the above great defects of the Galilean telescope had been fully recognised that it was suggested by Kepler that an instrument might be constructed with two convex lenses, instead of a convex and concave as formerly. This valuable idea, however, was not immediately put into practice, for it was not till the year 1637 that an instrument of this kind was really made (*see* (*b*) *Fig.* 25). The new telescope differed from the Galilean in having the single eye lens outside the focus of the large convex or object lens. Accordingly, the small glass was used simply as a kind of microscope to magnify the image already formed by the object glass. Huygens further improved this form of instrument by applying an eye-piece consisting of two convex lenses, which had the effect of giving a more distinct image than a single lens.

THE REFRACTING TELESCOPE.

In order to make the form of telescope proposed by Kepler as perfect as possible, the focus of the object lens had to be of a very great length. From the increase of the focal length, the size of the image in the focus is also increased, and the smaller the diameter of the object glass in proportion to the length of focus, the more perfect the vision of distant objects. Accordingly, this form of instrument was often constructed of great length. In 1672, Campan, of Bologna, made one which was no less than 136 feet long; Huygens one whose length was 123 feet, which he presented to the Royal Society of London; while Ausout possessed one 600 feet long, but it was so unwieldy that it could never be used. These extravagant lengths to which refracting telescopes at the commencement of the eighteenth century had attained were, as already mentioned, the outcome of the attempt to secure a powerful and perfect instrument. This the enormous focal lengths of the object lenses proved to be impossible in the refracting telescope. Though by increase of length the defects could be somewhat diminished, they were not altogether eliminated. The greatest imperfection was the *chromatic aberration*, or the coloured image produced by the unequal refrangibility of the different rays of colour which together produce white light. Owing to this difference of refrangibility a ray of white light, in passing through a single lens, such as the object glass of the above-mentioned telescope, is not refracted to the focus unaltered, but is decomposed or broken up into rays of various colours, and therefore the object when viewed with this instrument is so much coloured that distinctness of vision is impossible. Another great defect is

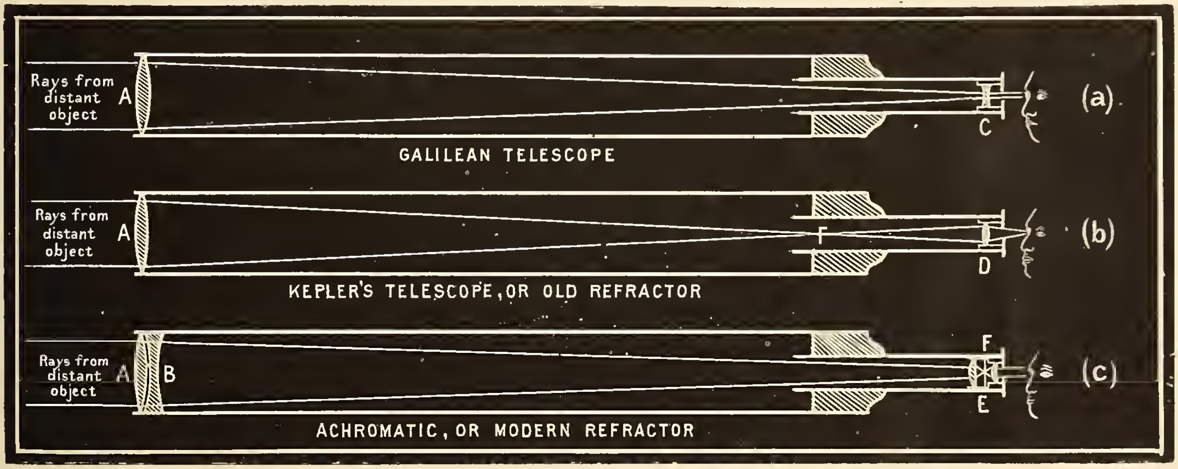


FIG. 25. THE REFRACTING TELESCOPE.

A Object Glass.
B Concave Flint Lens.
C Concave Eye-piece.
D Convex Eye-piece.
E Modern Achromatic Eye-piece.
F Focus of Object Glass.

spherical aberration, or indistinctness of the image produced by the spherical figure of the lens, which prevents all the rays from the object uniting at a common focus. This latter defect, however, was not of so much importance, inasmuch as it could be remedied by shaping the lens to a hyperbolic curve, or by making its two sides of different spherical curves.

For years philosophers had been led astray by the statement of Newton that it was impossible to remedy the defect of chromatic aberration, and it was not till the year 1758 that the English optician, Dollond, discovered by experiment that such was not the case. On carefully examining various kinds of glass, he found that some specimens had a greater dispersive power, or produced when used as a telescope a greatly more coloured image than other specimens. This suggested to him that a perfect instrument might be made by combining lenses of different kinds of glass. In carrying out this idea he was entirely successful, for Dollond soon found that if a convex lens of the least dispersive power, or composed of crown glass, were united with a concave lens of great dispersive power or of flint glass, a telescope could be produced that would give an image almost free from colour (*see* (*c*) *Fig.* 25).

This instrument received the name of the "Achromatic Telescope," or telescope that was free from colour. By this important invention of Dollond's the inconveniences of the old refracting telescope were done away with, for an instrument could now be made as powerful as the longest one hitherto employed, and only one-fifteenth of the length. Fortunately Dollond possessed a quantity of glass of superior quality, which enabled him at once to carry his invention to a high degree of perfection. The largest instruments he constructed were only about four inches in diameter, and this size was not surpassed for many years afterwards, owing to the difficulty experienced in securing flint glass of fine quality. It was not till the year 1830 that the manufacture of optical glass had been so far perfected as to enable opticians to construct achromatic telescopes with apertures of about nine inches. Several instruments of about this size were soon made for the observatories of Dorpat, Rome, and Munich, by the celebrated optician, Frauenhofer. As the manufacture of optical glass discs, for the construction of telescopic object-glasses, became more and more certain, opticians were encouraged to attempt the construction of larger instruments. In this they have been, within certain limits, entirely successful.

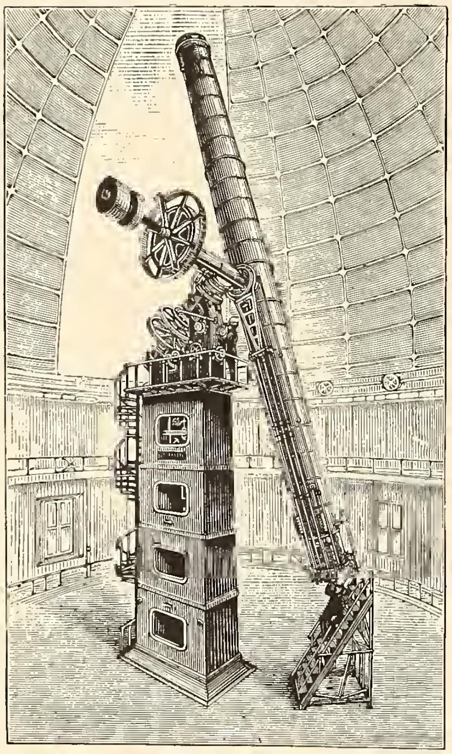
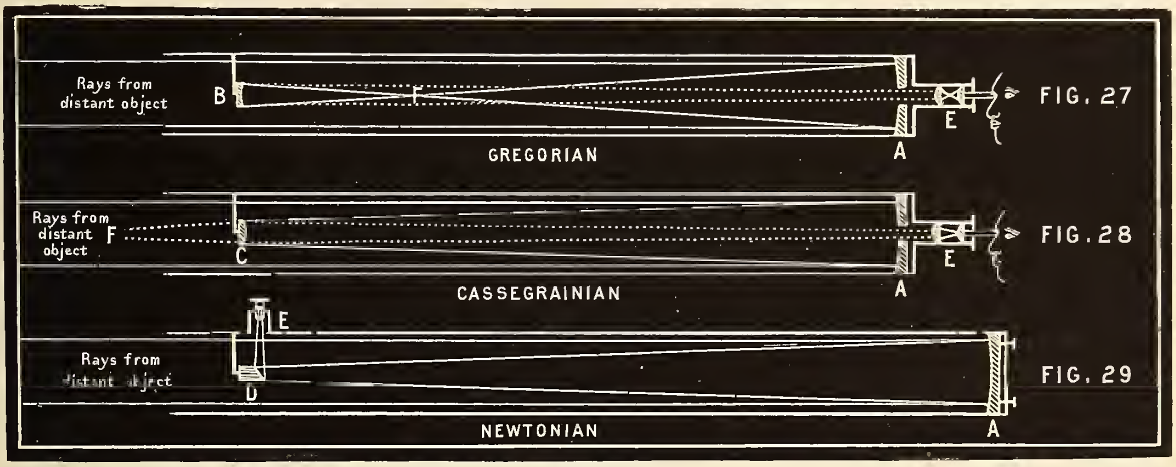


Fig. 26. THE LICK REFRACTOR.

Till the year 1860 achromatic telescopes had not been constructed larger than from twelve to fourteen inches in diameter. In 1862, however, one eighteen and a-half inches in diameter was completed for the Dearborn observatory, and this was soon followed by several others of slightly larger dimensions. In 1870 even this large size of object-glass was surpassed by the magnificent instrument, with an aperture no less than twenty-five inches, that was made for Mr. Newall, of Gateshead. The American opticians, not to be left behind by the English, endeavoured to construct even a larger instrument, and in this they were so successful that in 1873 an object-glass twenty-six inches in diameter was produced for the Washington observatory, so superior in quality that it has justly been considered one of the finest specimens of the optician's art. From 1873 the size of the refracting telescope rapidly increased. In 1879 one twenty-seven inches in diameter was constructed for the observatory at Vienna; and in the same year one twenty-nine inches, for the observatory of Paris. In 1880 one thirty inches was completed for the Nice observatory; in 1882 another the same size for the observatory at Pulkowa; and in 1888 the largest instrument of this kind yet constructed—viz., the great "Lick Refractor," with an aperture of no less than thirty-six inches (*see Fig.* 26). The difficulties to be overcome in the construction of this monster instrument were enormous. Numerous discs of glass had to be cast before suitable ones could be obtained, and it was only after about seven years of the most skilful labour possible in the present state of science and art that this optical masterpiece was successfully produced.

THE REFLECTING TELESCOPE.

Philosophers, realising the impossibility of overcoming the unequal refrangibility of the different coloured rays of light, gave up the idea of perfecting the refracting telescope, and directed their attention to the production of an instrument on some other principle. In 1639 Mersenne suggested the employment of a spherically-shaped mirror, for forming an image which might, as in the case of the refracting telescope, be afterwards magnified by means of a small convex lens. The Scottish astronomer Gregory, of Aberdeen, proposed a similar arrangement in 1663, without having had any previous knowledge of Mersenne's suggestion. Gregory's instrument was somewhat different in principle from Mersenne's, for he substituted a parabolic reflector, instead of the spherical one, for forming the image, and proposed the use of a small concave mirror placed outside the focus of the large one, and situated in its axis. By this means the image of the distant object formed at the focus of the large mirror would be reflected backwards through a small hole in the great speculum to the eye-piece lenses, where it was conveniently magnified, as indicated in Fig. 27. Believing in the success of his instrument, Gregory went to London for the purpose of having one constructed, but this he failed to accomplish, as no workman could be found who could produce a speculum, and unfortunately the project had to be abandoned.



FIGS. 27, 28, 29. DIFFERENT KINDS OF REFLECTING TELESCOPES.

THE REFLECTING TELESCOPE: *A*, Large speculum; *B*, Small concave mirror; *C*, Convex mirror; *D*, Small flat mirror; *E*, Eye-piece; *F*, Focus of large speculum.

About this time Newton had also turned his attention to the construction of reflecting telescopes, and having, in 1669, discovered a suitable alloy, he began to cast and grind a speculum with his own hands. Early in 1672 he completed two small instruments, one of which was about one inch in diameter, and had a magnifying power of thirty-eight (*see Fig.* 29*a*). The principle of Newton's telescope was somewhat different from that of Gregory's, as it had no small concave mirror, but a small perfectly flat one instead. This flat mirror was situated in the axis of the telescope, and inclined to it at an angle of 45 degrees, by which means the light rays were reflected through a hole in the side of the tube, and the image accordingly viewed at right angles to the axis of the instrument, as represented in Fig. 29.

The same year in which Newton completed his instrument, another form of reflector was proposed by Cassegrain. In arrangement, this instrument was similar to Gregory's, only, instead of a small concave speculum placed outside the focus, a small convex mirror situated inside the focus was suggested (*see Fig.* 29). In this latter form of instrument, the image, as in the refracting telescope, is inverted, while in Gregory's it is erect. Cassegrain does not seem to have actually constructed an instrument of this kind, and it was not till the year 1674 that a reflecting telescope with a hole in the centre of the large speculum was produced.

But little progress was made in the construction of reflecting telescopes for several years, owing to the difficulty experienced in obtaining a suitable alloy of metals for the mirrors. Accordingly, the first really powerful reflector was not made till 1718, when Hadley, the inventor of the sextant, constructed one, five feet long, on the Newtonian principle. This instrument was perfect enough to stand a magnifying power of 208 times, and revealed as much as an old refracting telescope of nearly 120 feet in length. From this time till the appearance of Herschel, reflecting telescopes were successfully constructed, but chiefly on the Gregorian principle. This form of telescope reached a high degree of excellence from the labours of Short, the Edinburgh optician. In 1732, Short turned his attention to the construction of Gregorian reflectors, and in a very few years afterwards surpassed every one else in their production. One of his finest instruments was so beautifully finished, and so perfect in figure, that the King of Denmark offered for it a sum of 1200 guineas.

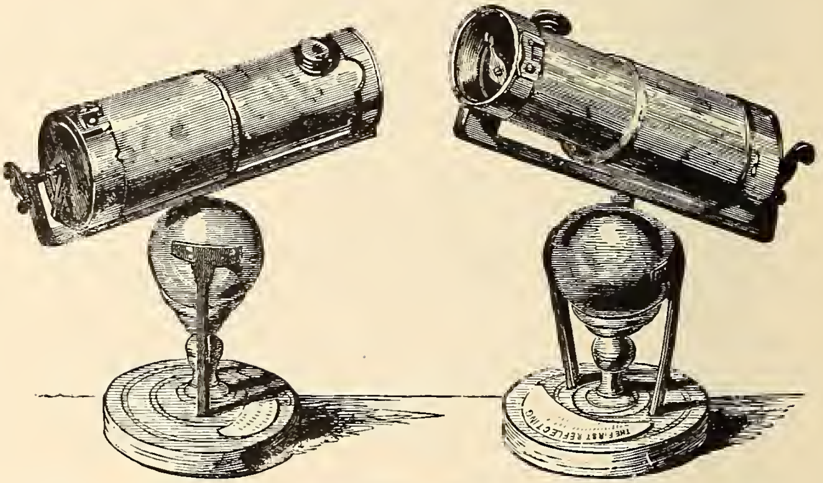


Fig. 29*a*. THE FIRST REFLECTING TELESCOPE, MADE BY SIR ISAAC NEWTON.

It is to Herschel, however, that we owe the general introduction of the reflecting telescope; for, as yet, no discoveries had been made by this form of instrument, and it was only by Herschel's success that the reflector became universally noticed. As early as 1774 Herschel, having had his attention directed to the wonders of astronomy by the temporary employment of a small Gregorian reflector, began to construct instruments for his own use. He was so impressed with what was revealed to him by this instrument, that he desired to have a similar one for himself; but the cost being too great for his means, he attempted the construction of a telescope with his own hands. In this he was entirely successful; for, after great difficulty, he completed a Newtonian reflector of five feet in length. This was soon followed by others, seven, ten, and even twenty feet long; and during his lifetime it is said that he constructed no less than four hundred instruments, of various powers and sizes. The largest of all his instruments was completed, under the patronage of George III., in 1789. In the construction of this telescope Herschel surpassed all his former efforts, for it was actually forty feet in length, and four feet in diameter. No sooner was this giant specimen of the optician's art directed towards the heavens than it was discovered that Saturn had two more satellites, which, owing to their faintness, had hitherto escaped the scrutiny of astronomers.

Herschel's telescopes were chiefly Newtonians, a form of instrument which is capable of being constructed with a high degree of perfection. One of the best specimens of this kind of reflector ever made was produced by Mr. Lassell, of Liverpool. It had a diameter of two feet, and was so perfect in figure that he was enabled to discover by it the eighth satellite of SATURN and the single satellite of NEPTUNE. This instrument was afterwards presented to the Observatory at Greenwich, where it is still used.

The largest telescope, however, which has been constructed on this, or indeed on any principle, was made by Lord Rosse. In 1840, this highly gifted nobleman completed a Newtonian reflector three feet in diameter, which, when employed in observation, was found to be an instrument of the highest excellence. But Lord Rosse was not satisfied with so large and splendid a telescope. Three years afterwards he gave to the world a still more striking proof of his great talent, and of the interest he had in the advancement of astronomical science, by successfully constructing a reflector six feet in diameter and fifty-six feet in length. This monster instrument is erected at Lord Rosse's estate at Parsonstown, in Ireland. It is suspended between two large walls, so that its movement is very limited, only amounting, in fact, to about eight degrees on either side of the meridian. Accordingly, a view of any celestial object can only be obtained when it is near its meridian passage, and only for about one hour at a time.

The largest reflecting telescope yet constructed with a pierced mirror, was erected in 1870 at the Melbourne Observatory. It has a diameter of four feet, and is of the Cassegrainian principle. This instrument has been chiefly employed in observing and photographing the numerous nebulæ and star clusters visible in the southern hemisphere.

THE MODERN REFLECTOR.

Till very recently it was usual to make the mirrors of reflecting telescopes of an alloy of copper and tin, a composition which is capable of receiving a high polish, and giving a brilliant reflection. But the specula thus produced were liable to tarnish through exposure to the weather, and could only be renewed by a process of polishing, an operation almost equivalent to the mirror's reproduction. This defect was in part remedied by Lord Rosse, who, from numerous experiments, greatly improved the composition of the alloy, whereby its liability to tarnish under exposure was diminished. Foucault, however, entirely overcame the defect by his invention, which consists in making once for all a speculum of *glass*, and depositing upon it an exceedingly thin film of silver. By this means the reflecting telescope was perfected, for not only was the great difficulty of the tarnishing successfully overcome, inasmuch as the film could be renewed as often as required without injuring the figure or delicate curve of the mirror, but a far more accurate curve could be given to glass than to a speculum formed of metal. Still further, the "silver-on-glass" reflector not only gives a more accurate image than the metal speculum, it also reflects more light. Though the silver film is only about the one-hundred-thousandth of an inch in thickness, it is nearly opaque, and at the same time so brilliant that it reflects ninety out of every hundred rays of light which fall on it. Accordingly, a modern reflecting telescope of about fourteen inches in aperture is a more powerful and perfect instrument than one of Herschel's eighteen inches in diameter. For several years the Author has employed one of these glass reflectors at his observatory with great advantage. It has an aperture of over thirteen inches, and a length of eleven feet; and is so perfect in construction that by its aid the finest views of the various celestial objects have been obtained.

APPLICATION OF THE TELESCOPE.

It was not till the year 1640 that the telescope was employed for sighting astronomical measuring instruments. Previous to that time the "optic tube" had been used only for viewing purposes, as it never occurred to astronomers that an angular instrument could be more accurately pointed to a celestial object by aid of telescopic sights than by the unaided eye. The young English astronomer, Gascoigne, seems to have been the first to have employed this method, by placing in the focus of the object-glass fine cross hairs. But Gascoigne went further: he not only employed telescopic sights, he also used the instrument for determining very minute angular distances. This he accomplished by placing in the focus of the telescope a graduated scale, or micrometer as it is now termed, by means of which the angular diameter of any celestial object could be measured, or the distance between close objects accurately determined.

Though Gascoigne seems to have been the first to have employed the micrometer, it is really to the Continental astronomers of about the middle of the seventeenth century that science is indebted for the application of the instrument to the telescope. Huygens proposed the use of an angular slip of metal situated in the focus of the object-glass, in such a manner that it could be pushed gradually inwards until the particular object was exactly eclipsed, from which its apparent diameter could be found. The Marquis of Malvasia invented a different form of micrometer, consisting of a reticule, or fine network of silver threads, the distance between which could be accurately determined by observing the intervals occupied by a star or planet in passing between them in its apparent diurnal movement. The most valuable invention of this kind, however, was due to the independent suggestions of Auzot and Hooke. These astronomers pointed out that the reticule micrometer would be of considerably more value for delicate measurement if one of the threads had a parallel movement, by means of a fine screw. Accordingly, this form of micrometer, which is the one now principally employed, consists of two sliding metal frames, across which two exceedingly fine wires are stretched (*Fig.* 30). By means of an accurately made screw the frames which carry the wires are made moveable, and therefore the wires can be placed at any required distance from each other. As the distance between the threads of the screw is accurately known, the number of revolutions, and part of a revolution, which the screw has made in moving the frame from the point where the two wires were exactly behind each other, to the position where they embraced the diameter of the object to be measured, is all that is required to be known in order to determine the angular distance. To simplify the numbering of the revolutions, a scale is inserted parallel to the screw, by which means the exact number of revolutions which the screw has passed over can be ascertained by observation, while the exact portion of a revolution can likewise be found, from the large graduated head of the screw. Thus, for example, the apparent diameter of a planet can be determined by first bringing the two wires, B, C, together by the screw movement, and then turning the screw until the wires are made to embrace the planet's disc, when, by means of the scale and graduated head, the number of revolutions, and part of a revolution, can be easily found, and from these the angular diameter of the planet. When this instrument is constructed with great refinement, it is capable, when applied to a large telescope, of measuring very minute angles, not unfrequently to the fraction of a second of arc.

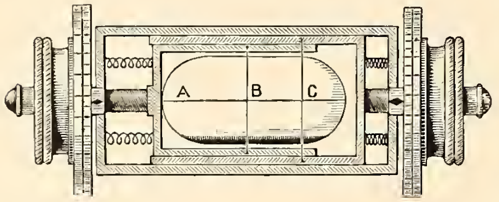


FIG. 30. THE PARALLEL WIRE MICROMETER.
A, Horizontal wire; B, C, Movable vertical wires.

THE TRANSIT INSTRUMENT.

This most valuable instrument of modern astronomy, by means of which the positions of the various heavenly bodies have been so accurately determined, was invented in 1644 by the Danish astronomer, Roemer. Previous to that time the positions of the different celestial objects had, for the most part, been determined by observations when out of the meridian. Tycho had indeed seen the great advantage of meridional observations over those made when the object was in other parts of the sky, but the method he adopted did not give much more accurate results than those already employed. His arrangement consisted of a large mural quadrant, whose plane was made to coincide as nearly as possible with the meridian. By means of a hole in the wall, near the apex of the instrument, in which a sight was placed, and a corresponding sight on the graduated limb of the quadrant, the instant of a celestial object's passage across the meridian was determined; while the position of the lower sight on the limb gave the exact altitude, from which its equatorial distance or declination could be found. It was by such means that Tycho sometimes determined the right ascension and declination of the different heavenly bodies, or those important celestial co-ordinates which are employed by astronomers for indicating the positions of objects on the star-sphere. After the telescope had been some time in use, astronomers, carrying out Roemer's suggestion, were enabled to determine these positions with greater accuracy by means of a much smaller and less cumbersome apparatus — viz., the transit instrument.

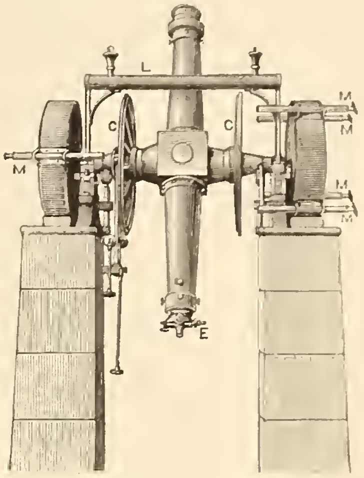


FIG. 31. THE TRANSIT INSTRUMENT.
C, Large graduated Circles.
E, Micrometer Eye-piece.
L, Level.
M, Microscopes for reading Divisions on Circles.

This instrument, as one might suppose, received its name from being designed to observe the transit of celestial objects across the meridian. Accordingly, it consists of a telescope mounted on trunnions like a cannon, so as to have but one movement—viz., in a vertical plane. This direction of movement is, by accurate adjustment, made to coincide with the meridian, and, consequently, the horizontal axis on which the instrument swings lies exactly east and west. The extremities of the axis, or the pivots as they are called, rest on "Y" bearings, which are securely fixed on the top of two massive stone piers or pillars (*see Fig.* 31). These pivots require to be formed of some hard material and must be of the most accurate construction, for not only is it absolutely necessary that they should be of exactly the same size, but also continuations of the same geometric cylinder. When this is the case, and the instrument accurately adjusted to the meridian, the centre of the field of view, or the optical axis of the instrument, will, when the telescope is turned completely round, trace out accurately the meridional great circle.

By this means the exact instant of an object's transit over the meridian can be found. To insure the greatest possible accuracy, the field of view is divided into spaces by seven exceedingly fine wires, or, very often, lines formed by threads of spider web (*see Fig.* 32). The time of the object's passage across each of the wires is very carefully observed, and the *average* of these times gives more accurately than a single observation the instant of meridian transit. In order to set the instrument to the altitude of the object to be observed, a small graduated circle is attached, the index of which, when adjusted, enables the observer to place the telescope at the required angle for the object's passage through the field of view.

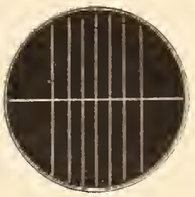


FIG. 32. THE FIELD OF VIEW OF THE TRANSIT INSTRUMENT.

Until very recently the instants of transit were determined by "eye and ear" observation, the eye discerning the instant of the object's bisection by the wire, and the ear counting the beats, or seconds of the astronomical clock. Now, however, this is accomplished more simply and accurately by the use of an instrument called "the chronograph." This instrument consists of a revolving drum, driven by clockwork, on which there is placed a sheet of paper. As this cylinder revolves, a small electro-magnetic pen is made to move gradually along, and at the same time caused to record notches on the paper at regular spaces, or at perfectly regular intervals of time. This is accomplished by an electrical arrangement connected with the observatory clock. With each beat of the pendulum the circuit of the battery is closed and broken again. The closing of the circuit gives a small lateral movement to the registering pen, so that the seconds of the standard clock are accurately recorded on the sheet of revolving paper. By means of a second pen connected with a key, which the observer holds in his hand, an intermediate notch can, at any time, be made. Whenever a star, or other celestial object, is exactly bisected with one of the wires, the observer has only to touch the key in order to cause the pen to make a mark on the paper, and permanently record the instant of transit; for, by observation of the position of the notch thus made, not only is the exact second determined, but, by subdivision, the smallest fraction of a second as well.

The transit instrument is accordingly employed for determining the instant of meridian passage, which it is capable of doing with the greatest accuracy, and from this the right ascension, or distance of an object from the vernal equinoctial point. It can only, however, determine the altitude very approximately, as the circle attached to it is too small for accurate measurement of arcs on the meridian. Until recently these arcs were measured by means of a large circle of from six to eight feet in diameter, firmly attached to a massive stone wall built in the plane of the meridian. By means of several microscopes, and minute divisions on the limb, the altitude, and from this the declination, could be fixed with great accuracy. Accordingly, by the employment of these two instruments—viz., the transit instrument and the mural circle, astronomers are enabled to minutely determine the celestial co-ordinates.

The use of these instruments, however, requires separate observations, and, therefore, different observers. To overcome this disadvantage, and to simplify the observations as much as possible, an instrument has been designed to enable a single observer to determine simultaneously the right ascension and declination. This instrument, as might be supposed, is simply a combination of the two above-mentioned—viz., the mural circle and the transit instrument, and is called the meridian, or transit circle. It consists essentially of a transit telescope proper, with large graduated circles attached to its axis in such a manner as to revolve with the telescope. Its construction requires the greatest mechanical skill, guided by the highest scientific knowledge. All the parts must be made with the greatest care, and in such a manner as to insure perfect rigidity, and freeness from the slightest vibration and flexure, defects which would vitiate the observations. Usually the circles of this type of instrument have a diameter of from two to four feet, as it is found that if constructed of larger size, less accuracy is actually attained, owing to the greatly increased strain and flexure produced by the consequent increase of weight. In dividing these circles as precisely as possible, and in providing the greatest accuracy in reading the graduations, the utmost resources of mechanical art are employed. As, however, it is absolutely impossible in the construction of any instrument to reach perfection, minute errors are accordingly produced, which it is the duty of the astronomer to discover, and allow for, in his observations. By means of this instrument the declination, or north polar distance, of an object can be determined to within less than one second of arc, an angle which is so minute that, even on a circle of about four feet in diameter, it only amounts to the *one-ten-thousandth* of an inch, which shows the necessity for the finest workmanship.

THE OBSERVATORY CLOCK.

The necessary adjunct to the above-mentioned instruments is the sidereal clock, for, without accurate time, the instant of meridian passage would be unknown, and the right ascension could not be easily determined. It is only within the last two hundred years that reliable time-keepers have been obtainable, as previous to the year 1657, no certain method for controlling a clock movement was known. Though Galileo had already discovered the law of the pendulum, it was Huygens who first applied that gravitational governor to the construction of clocks—an application which has done as much to advance astronomical science as the invention of the telescope.

In construction the astronomical clock differs from that of any other, only in its parts being more carefully produced. As a matter of convenience it is made so as to beat exact seconds of time. This depends entirely on the length of the pendulum, whose slowness of movement increases with its length. The proper length that a pendulum ought to have in order to beat true seconds, was first determined by Huygens, who found that approximately it amounts to about 39 inches. It is slightly different, however, for different latitudes, increasing in length as the place approaches the poles. As the exact indication of time entirely depends on the regularity of the pendulum's vibrations, it is necessary that it should be invariable in length. This it is difficult to preserve, as no single substance has ever yet been found of which a pendulum can be constructed which is not liable to contract and expand under changes of temperature.

To overcome this defect, the compensated pendulum has been invented—a pendulum which under any change of temperature retains its adjusted length. The one most commonly used is known as Graham's mercurial pendulum, after its inventor. It consists of a long steel rod, suspended by a spring, at the foot of which is a glass jar three or four inches in diameter filled with mercury (*A*, *Fig.* 33). By this means the centre of gravity of the mass of mercury always remains at the same distance from the centre of suspension. Under an increase of temperature, for example, the steel rod lengthens, but as the mercury also expands, it rises in height, and just the required amount to keep the centre of gravity at the same distance from the centre of suspension. Another form of composition pendulum is a modification of the old "gridiron" one invented by Harrison. As indicated in the figure *B*, this pendulum is composed of a zinc tube and steel rods. These are arranged with the rods outside the tube, and supporting it at the bottom; while an internal steel rod, which carries the heavy leaden bob, is suspended from the top of the tube. While the steel rods lengthen from a rise of temperature, the zinc tube also increases its length, but in an upward direction, and, therefore, the lead cylinder is raised by the tube exactly the amount it was lowered by the expansion of the rods, or under changes of temperature the length of the pendulum remains invariable.

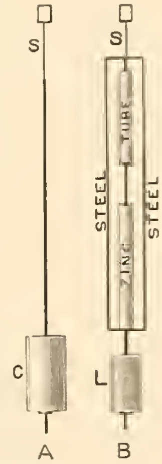


FIG. 33. THE COMPENSATED PENDULUM.

S, *Suspension Spring*;
C, *Jar of Mercury*;
L, *Cylinder of Lead*.

The next important part of the astronomical clock is the escapement, or wheel, which is under the immediate control of the pendulum. The one generally used is known as Graham's "dead-beat" escapement, from the second hand beating the seconds without any recoil. With each swing, the pendulum allows the escape wheel to advance one tooth, and thus indicates on the dial one second of time. For convenience of reading the time, the second hand of astronomical clocks is very conspicuous, while the hour-hand makes but *one* revolution per day, instead of two as in ordinary clocks, the hours being numbered continuously to twenty-four.

The clocks used in observatories are of two kinds—viz., the mean time clock and the sidereal clock. The former of course indicates the true mean solar time, and consequently makes a complete revolution once every twenty-four hours; while the latter has no direct connection with solar time, as it completes a revolution in twenty-three hours fifty-six minutes, or in the time occupied by the earth in making a complete rotation. Thus the sidereal clock keeps pace with the apparent movement of the star-sphere, and therefore indicates the position of the stars in the sky. It is so adjusted that it indicates 0h. 0m. 0s. when the vernal equinox, or the first point of Aries, is on the meridian, and accordingly shows at any time the hour of right ascension that is passing the meridian, or indicates, as it is called, the sidereal time. When accurately regulated, on the other hand, it is employed, in conjunction with the transit instrument, in determining the right ascension of objects, for the exact instant of time indicated by the clock when the object is bisected by the central wire in the focus of the telescope is its true right ascension, or distance in time from the first point of Aries.

THE EQUATORIAL.

This is the name given to a certain style of mounting for the telescope when principally employed for viewing purposes, as by means of it the instrument can be made to sweep out curves on the celestial sphere parallel to the equator. Accordingly, the principal axis round which the telescope swings is not upright, or vertical as in the case of small instruments, but inclined to the horizontal at an angle equal to the latitude of the place, and directed to the pole of the heavens. The chief axis, or the polar axis as it is called, is thus placed exactly parallel to the axis of the earth, and, therefore, by one movement, the instrument can follow the apparent course of an object produced by the rotation of our globe. Passing through the polar axis, and lying at right angles to it is another one called the declination axis, to which the telescope is fixed. By means of this axis the telescope can be pointed to any particular part of the celestial sphere, or to any required declination. This is conveniently accomplished by aid of a graduated circle attached to the opposite end of the arm which carries the declination axis. At the foot of the polar axis there is a similar circle, called the hour, or right ascension circle, by means of which the telescope can be pointed to any hour angle, or distance in time east or west of the meridian. Thus, by aid of these two circles, the telescope can be directed to any part of the heavens, or pointed during the day or night to any invisible object. If, on the other hand, an object be discovered, its position in the heavens, or its right ascension and declination, can at once be determined by reading the declination and right ascension circles.

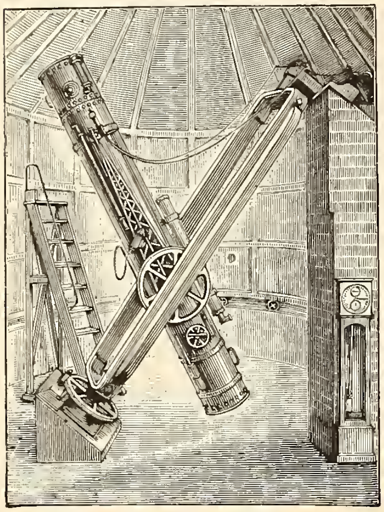


FIG. 34. THE EQUATORIAL TELESCOPE.

The equatorial mounting can be divided into two kinds—viz., the English and German. In the former the telescope swings between two long pillars which terminate in two pivots. These are supported at top and bottom, and accordingly form the polar axis of the instrument. This form of mounting is adopted at Greenwich Observatory for the large refracting telescope. The Author has successfully employed this style for his reflector of over thirteen inches aperture, as indicated in Fig. 34.* In this case the polar axis is about fourteen feet in length, and is so rigidly constructed that great steadiness and accuracy of movement is obtained, from which the Author has been enabled to produce several very fine celestial photographs (*see Frontispiece*).

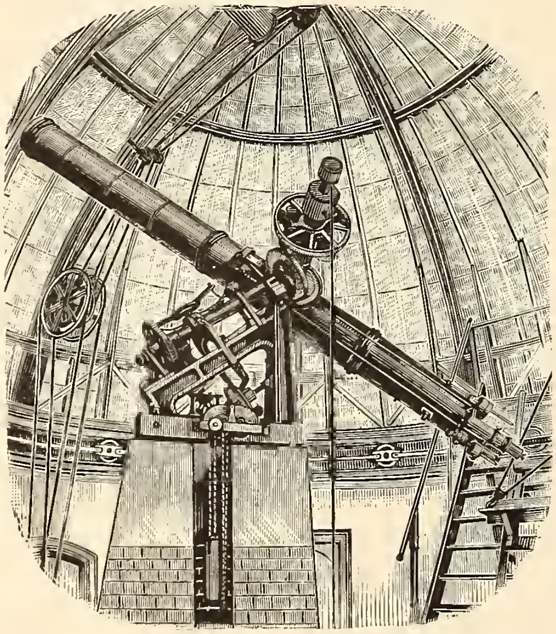


FIG. 35. A MODERN REFRACTING TELESCOPE EQUATORIALLY MOUNTED.

One of the disadvantages of the English equatorial is the impossibility of obtaining by it a view of any object near the pole. This is entirely overcome in the German mounting, which is now almost universally employed for the refracting telescope. In this form the polar axis is comparatively short, and the telescope, instead of swinging centrally, as in the case of the English form, is supported on one end of the declination axis, its weight, which is generally considerable, being counterpoised by a system of heavy weights, sliding on levers at the other end of the declination arm. Figure 35 is a representation of this style of mounting applied to a large refractor (*see also Fig.* 26); while Fig. 36 is a representation of the German equatorial mounting applied to a glass reflecting telescope twelve inches in diameter, constructed by the Author.

The great advantage of the equatorial mounting for large instruments, over any other, is derived from its convenience for following celestial objects with only one motion. If the principal axis were vertical, as in the altitude and azimuth stand employed for small telescopes, the instrument would require to be raised, when following an object in the eastern portion of the sky, and continually lowered, when viewing in the west. The equatorial, however, as already mentioned, from the inclination of the polar axis, is enabled to trace out curves on the star-sphere exactly the same as those described by the apparent movement of celestial objects. As this motion is produced by the rotation of our globe it is perfectly uniform, and consequently clockwork can be applied to drive the polar axis at the same rate as the earth. By this means celestial objects can be viewed for hours at a time without passing out of the field of view, as by the clock movement the telescope is made accurately to keep pace with the motion of the object. Celestial photographs can also, by aid of the driving clock, be obtained, for, notwithstanding the apparent motion of the heavenly bodies, the movement of the telescope can be so accurately regulated, that even the smallest stars can be imprinted on the photographic plate with perfectly round discs, which they could not have if the instrument had the slightest irregular movement.

---

* The instrument of which Fig. 34 is a view, was presented to the City of Edinburgh Observatory by Robert Cox, Esq., M.A., F.R.S.E.

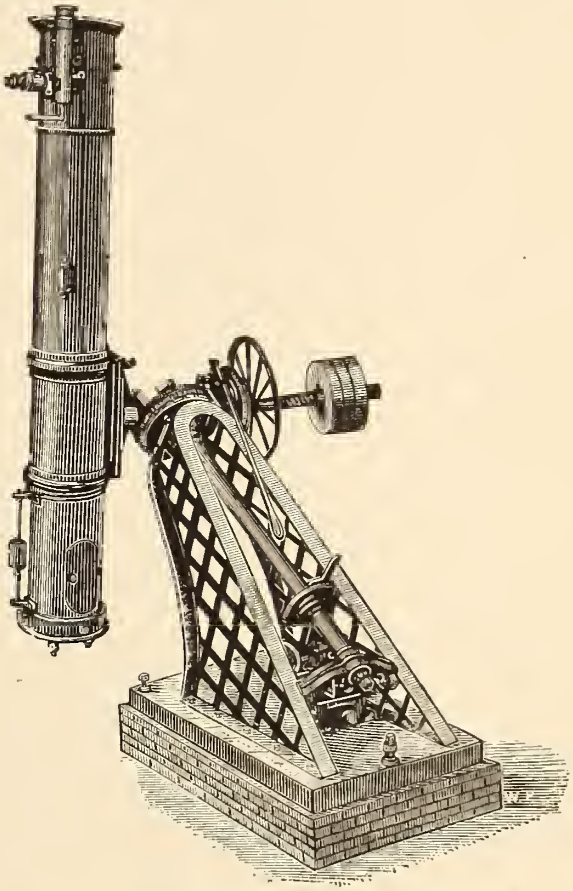


Fig. 36. A modern reflector equatorially mounted, constructed by the author.

THE SPECTROSCOPE.

This is certainly the most wonderful instrument employed by the astronomer, though only of comparatively recent invention. Although the decomposition of light, produced by being passed through a prism or wedge-shaped piece of glass, was discovered by Kepler and Newton, it was not till 1814 that the spectroscope was first used. Previous to that year, Wollaston, while casually looking through a prism at a narrow opening in a window, observed that the coloured band, or spectrum, was crossed by a number of dark lines parallel to the slit. This led to the invention of the spectroscope, and to the mapping of the lines by the German optician, Fraunhofer (*see Plate* 19.) The essential part of this instrument consists of a triangular prism, by means of which the light is dispersed or broken up into a coloured band. But the light in passing through a prism is not only decomposed, it is also refracted out of its original course, the amount of divergence depending on the colour. The nearer the ray approaches the red colour, the less it is refracted, and thus the red or yellow rays in a beam of white light are not bent so much out of their course as the blue or violet rays. The image of the slit of the spectroscope, when viewed through a prism, is, therefore, of a considerable breadth, and contains all the colours of the rainbow.

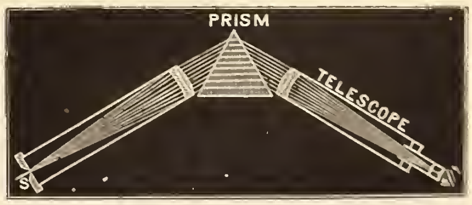


Fig. 37. Simple spectroscope.

In its simplest form the spectroscope contains only one prism, which is placed between two telescopic tubes (Fig. 37). At the outside end of one tube there is placed the slit *S*, a very narrow opening, which, by a delicate screw movement, can be accurately adjusted to the required breadth. At the other end of the same tube, or next the prism, a small achromatic lens is situated, for the purpose of causing the diverging rays from the slit to pass through the prism parallel to each other. After passing through the prism, and being refracted by it towards its base, the rays now fall on the object-glass of the small viewing telescope, by which means they are bent to a focus, where the spectrum is formed, and where it can conveniently be magnified by the eye-piece lens.

When applied to the telescope, and especially when used in examining the light of the sun, a considerable number of prisms are often employed in order to secure as great a dispersion as possible. Sometimes, too, instead of a battery of prisms, a "diffraction grating," or flat piece of speculum metal ruled with numerous fine lines, so close together that there are at least 15,000 in a single inch, is used, especially when the production of a very highly magnified solar spectrum is desired. Figure 38 is a representation of a double prism astronomical spectroscope in the possession of the Author. This type of instrument is chiefly employed in the examination of the spectra of stars; and, when so used, a cylindrical convex lens conveniently takes the place of the slit. For the solar spectrum, however, and for the spectra of planets and nebulæ, the slit cannot be dispensed with. In the Author's instrument the slit can be very accurately adjusted by means of a fine screw with graduated head, which records an opening as small as the thousandth of an inch; while, for the purpose of measuring the distances between the lines of the spectrum, a delicate micrometer, in the focus of the viewing telescope, registers as minute a distance as the ten-thousandth part of an inch.

As already mentioned, Wollaston, at the beginning of the present century, accidentally discovered that the solar spectrum contained numerous dark lines, and Fraunhofer with great care determined the positions they occupied. These lines were soon found undoubtedly to belong to the sun, as when the slit of the instrument was directed towards some artificial light, only a coloured band, or continuous spectrum was observed. It was not, however, for many years after their discovery, that their existence could be accounted for. Now it is known with certainty how they are produced. Each incandescent body, whether solid, liquid, or gaseous under a high pressure, gives a continuous spectrum, without lines; while, if it is surrounded with vapours, these will absorb certain parts of the spectrum, and produce dark lines. These lines would appear luminous if the vapours surrounding the incandescent mass were glowing with heat, and the overpowering brilliancy of the incandescent body removed. This is proved to be the case by what is known as the reversal of the spectrum. When, for example, the metal sodium is burnt in the colourless Bunsen flame, two bright lines are seen in the yellow part of the spectrum (*see "D" line, Plate* 19). If, on the other hand, a brilliant light be placed behind the sodium vapour, two dark lines will be seen instead, and these will be found occupying exactly the *same* position in the spectrum as the bright lines. Applying this experiment to the sun, the bright sodium lines can, by means of a small reflecting prism placed in front of the slit of the spectroscope, be seen in the field of view alongside of the solar spectrum. When thus examined it is found that they *coincide exactly* with two dark lines in the spectrum of the sun, which proves that these latter owe their existence to sodium vapour surrounding the solar globe.

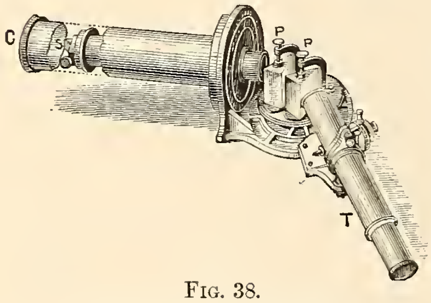


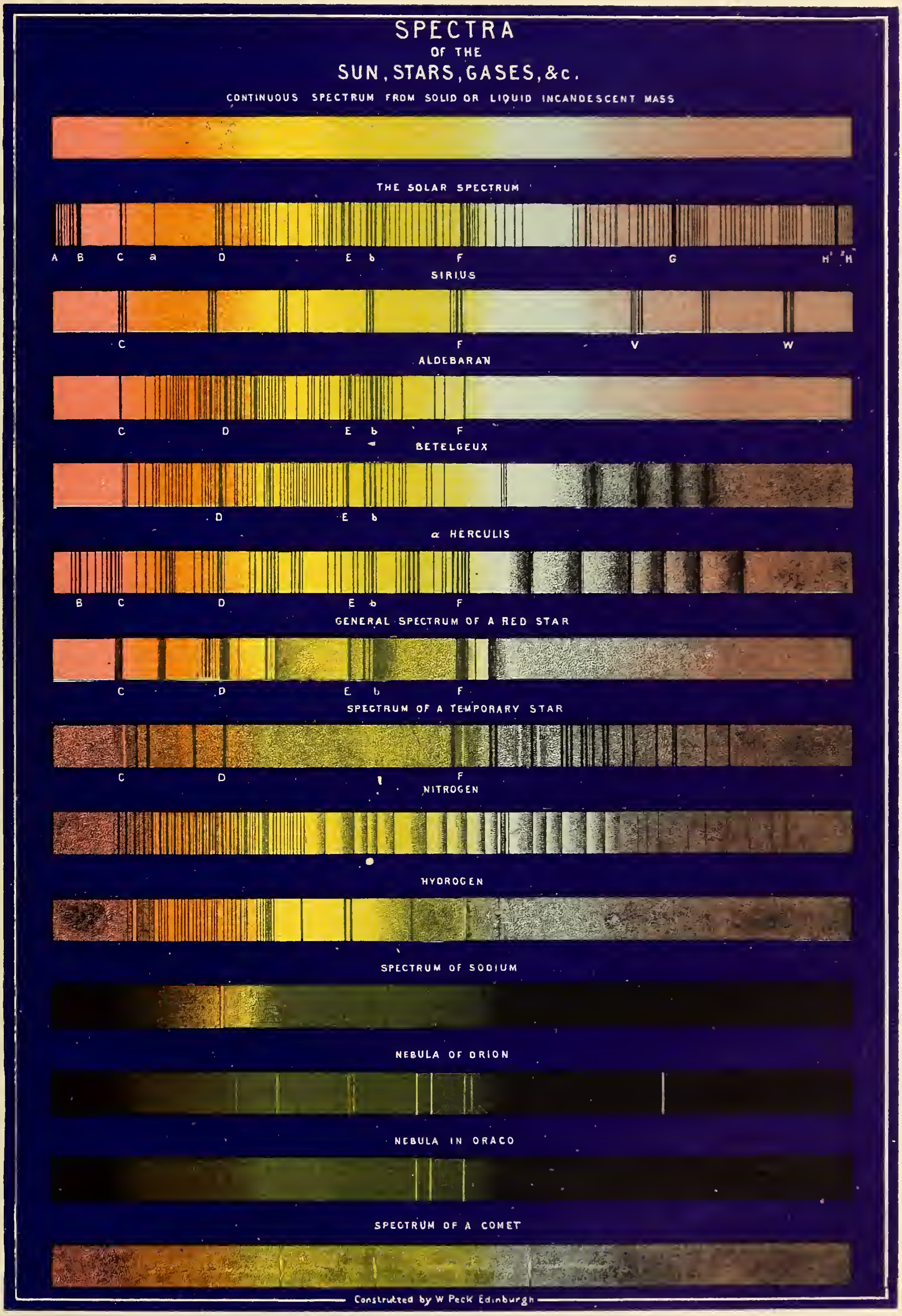
Fig. 38.
THE AUTHOR'S SPECTROSCOPE.
C, Cylindrical Lens.
S, Slit.
PP, Prisms.
T, Viewing Telescope.

In the same manner hundreds of other lines have been identified, and accordingly the composition of the solar atmosphere revealed. The following elements are known with certainty to compose a large portion of the vapours surrounding the sun:—

Barium.
Calcium.
Chromium.
Cobalt.
Hydrogen.
Iron.
Magnesium.
Manganese.
Nickel.
Platinum.
Sodium.
Titanium.

while there is the strongest evidence for supposing that the following also exist in the solar atmosphere:—

PLATE 19.


SPECTRA
OF THE
SUN, STARS, GASES, &c.
CONTINUOUS SPECTRUM FROM SOLID OR LIQUID INCANDESCENT MASS
THE SOLAR SPECTRUM
A
B
C
a
D
E
b
F
G
H'
H
SIRIUS
C
F
V
W
ALDEBARAN
C
D
E
b
F
BETELGEUX
D
E
b
α HERCULIS
B
C
D
E
b
F
GENERAL SPECTRUM OF A RED STAR
C
D
E
b
F
SPECTRUM OF A TEMPORARY STAR
C
D
F
NITROGEN
HYDROGEN
SPECTRUM OF SODIUM
NEBULA OF ORION
NEBULA IN DRACO
SPECTRUM OF A COMET
Constructed by W Peck Edinburgh

Aluminium.
Cadmium.
Carbon.
Copper.
Lead.
Molybdenum.
Oxygen.
Palladium.
Uranium.
Vanadium.

Like the solar spectrum, the spectra of the stars are also crossed with several dark lines, which proves that these orbs are indeed suns, or, like the great centre of our system, incandescent gaseous masses surrounded with glowing vapours. But not only does the existence of the lines in the stellar spectra prove that these orbs are suns, and that they are composed of many well-known terrestrial materials, the difference of the grouping of the lines also reveals, as mentioned in Chapter III., the fact that the stars are arranged into different groups.

The nebulæ, on the contrary, give no dark lines at all, not even a continuous spectrum, but instead a spectrum composed only of bright lines. This shows that they are in a condition vastly different from that of the stars, that instead of being incandescent gaseous masses under great pressure, they are simply uncondensed masses of luminous vapour.

Not only, however, is the spectroscope employed in the analysis of the various heavenly bodies, it is also used with success for determining the velocity at which they are moving. This it is capable of doing irrespective of the object's distance; as its motion affects the velocity of the light rays travelling from it towards us. If, for instance, a star be journeying away from our-system, the light waves will be lengthened, and if travelling towards us, they will be shortened by the actual velocity of the star's motion in the line of sight. Accordingly, the lines of the stellar spectra do not exactly coincide with those formed by the burning of terrestrial substances, but are slightly displaced, to the one side or other, of the corresponding terrestrial spectral lines. As difference of colour is simply a difference of length in the waves of light, the violet being the shortest, and the crimson the longest, the direction of displacement gives the direction of the star's motion, and the amount of displacement the actual speed of the star in the line of vision. If, for example, the lines are displaced towards the blue end of the spectrum, then the motion of the star is being added to the velocity of light, which shows that the star is moving towards us. On the other hand, if the displacement happens to be directed away from the blue end, or towards the red part, the waves have been lengthened by the star's velocity in travelling away from our system. By this means the speed at which the stars are journeying in the line of vision, either from or towards us, can be determined with approximate accuracy; for the amount of displacement of the lines measured in the field of the spectroscope, gives the rate at which the star is moving in proportion to the velocity of the wave lengths of light; and from this the actual velocity of the star in its orbit can be found (*see* page 18).

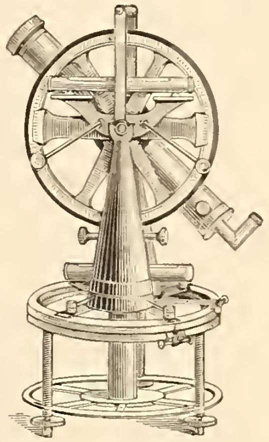


Fig. 39.
ALTITUDE AND AZIMUTH INSTRUMENT.

OTHER ASTRONOMICAL INSTRUMENTS.

Besides the instruments already mentioned for determining the positions of objects, there is the Altitude and Azimuth instrument. As its name implies, this instrument is constructed for the purpose of determining horizontal and vertical angles. This it is capable of doing with great accuracy, by means of two finely graduated circles situated at right angles to each other. Figure 39 is a view of one of these instruments used by the Author. By aid of the delicate levels attached to the circles, the instrument can be accurately adjusted, and valuable observations made of positions of celestial objects when situated at any part of the heavens.

Another very important instrument employed in observatories is the Prime Vertical Transit. This, like the ordinary transit instrument, seems to have been invented by Roemer. It is simply a transit instrument, but, instead of swinging in the meridian, is adjusted to the east and west line, or to the prime vertical. Roemer did not use this instrument much, and it was not employed by astronomers till Bessel pointed out its great value for accurately finding the latitude by means of time observations of stars crossing the prime vertical, near the zenith, and also for determining the declinations of stars.

Among the portable instruments that the astronomer sometimes employs, the most important is the sextant. Though Hooke, as early as the beginning of the eighteenth century, had suggested the use of a reflecting instrument for measuring angles, and though Newton was doubtless the first who actually constructed such an instrument, or one resembling the modern sextant, it is to Hadley that science is indebted for its employment. Without knowledge of its previous invention, this invaluable instrument was re-invented almost simultaneously and independently by Hadley, in England, and Godfrey, in America, in the year 1730.

Unlike other astronomical instruments, the sextant can be employed at sea, as observations made by it are not in the slightest affected by the motion of the ship, which renders it of the greatest service to the mariner, enabling him, in conjunction with the chronometer, to determine his position at sea with surprising accuracy. As represented in Figure 40, the modern sextant consists of a light metal framework, with suitable handle at back. This frame carries the graduated limb of the instrument, and the small mirrors for reflecting the images of the celestial object and the distant horizon. The limb only contains part of a circle, and is usually graduated to 120 degrees. On the limb, and moving round the centre of its arc, is the index arm with index mirror at top, or immediately over the pivot of the instrument. On the left-hand side is a stationary mirror, the top half of which is unsilvered. This is called the horizon-glass, because it is through this that the horizon is viewed. When employed in measuring altitudes, the instrument is held vertically, and turned so that the horizon is seen by the small telescope through the transparent part of the horizon-glass. The index arm is then moved outwards, or towards the horizon-glass, until the index mirror, which moves with it, reflects the celestial object from the silvered portion of the horizon-glass into the field of view of the small telescope. The object and the horizon can thus be made apparently to touch, and the angle, degrees, minutes, and seconds, which the arm has moved over in bringing the index-glass into this position, as indicated on the graduated limb, is the angular height of the object above the horizon.

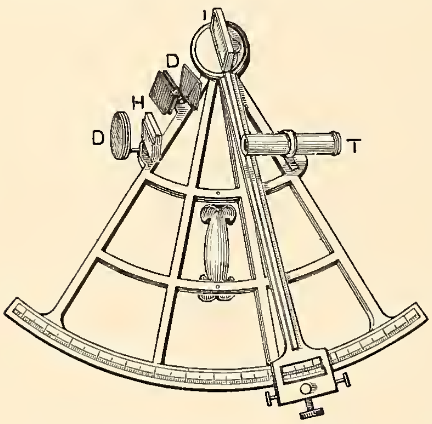


Fig. 40. the sextant.

T, Telescope. *I, Index Glass.*
H, Horizon Glass. *D, Dark Glasses.*

There are several other instruments employed by astronomers for special work, and therefore of special design, but they are not of so great importance as those already mentioned. Among these may be mentioned the zenith telescope, the heliometer, the photometer, or instrument for measuring the quantity of light emitted by the various stars; the siderostat, heat measuring appliances, and celestial photographic apparatus.

SUITABLE INSTRUMENT FOR A PRACTICAL STUDY OF THE HEAVENS.

Having described the more important instruments employed by astronomers, it only remains to mention one that could be advantageously used by the reader in a practical study of the different heavenly bodies. The smallest size suitable for this purpose is either a refracting telescope of about three inches aperture, or a silvered glass reflector with a diameter of about four inches. By means of such an instrument, which may conveniently be used at an open window, striking views can be obtained of the more interesting celestial objects, as it would reveal the spots in the sun, the mountains of the moon, the phases of Mercury and Venus, the belts of Jupiter, the ring of Saturn, and many double stars. Such an instrument, if of good quality, will bear a magnifying power of from two to three hundred times, depending on the kind of object examined.

The magnifying power of any telescope depends entirely on the proportion between the focal lengths of the object-glass and eye-piece lens. If, for example, the object-glass has a focal length of forty inches, and the eye-piece one inch, then the magnifying power would be forty. If the eye-piece, on the other hand, were only half-an-inch in focus, then the power would be double this, or eighty diameters. Accordingly, the greater the proportion between the focal lengths of the eye-lens and object-glass, the higher the magnifying power.

This, however, cannot be increased indefinitely, as each instrument has a limit beyond which additional magnifying power cannot be applied. In the first instance, the power is regulated by the size of the object-glass, as an increase of power without increase of aperture greatly diminishes the brilliancy of the object. When brightest, the magnifying power is the *lowest possible* that can be applied, and this lowest magnifying power also depends on the diameter of the object-lens. If less than a certain proportion to the aperture, the diminished image of the object-glass in the eye-piece would be larger than the pupil of the eye, and, consequently, all the light from the object-glass would not enter the eye at one time. As the diameter of the pupil of the eye amounts, on the average, to about one-fifth of an inch, a sufficient magnifying power has to be applied to diminish the image of the object-lens to this size. The lowest magnifying power that will do this is easily determined for any size of telescope, by multiplying the diameter of the object-glass by five; so that in a three-inch instrument the lowest magnifying power will be fifteen times.

When the magnifying power, as above mentioned, is the lowest possible, the instrument has then the greatest space-penetrating power of which it is capable. Accordingly, this power depends entirely on the aperture of the telescope, irrespective of the focal length; while the magnifying power, though certainly limited by the diameter of the object-glass, yet depends in a manner on the focus. But there is still another power that a telescope may be said to have—one which depends neither on the aperture nor on the length of focus, but on the quality of the object-glass itself. This, of course, depends on the nature of the glass and the fineness of its polish, and also on the accuracy of its curved surfaces. If these details are not attended to in the construction of the instrument, it will not be at all suitable for astronomical purposes, though it may give fairly good views with low powers of distant terrestrial objects.

It is, therefore, necessary to test the instrument for any defects that it may have. For this purpose a sheet of printed figures in the daytime, and double stars at night, are the most suitable. If not truly corrected for chromatic aberration, the edges of the figures on the sheet of paper in the daytime will appear coloured; while if spherical aberration exists, it will be revealed in the general mistiness of the image when at its sharpest focus. During the night the same defects will be at once perceptible when the instrument is directed to the moon, planets, or stars. The Moon, Venus, and Jupiter are the severest test-objects for achromatism; while double stars easily reveal the more serious defect of spherical aberration. The Pole Star is a particularly good object for the test of defining power, as the faint companion can only be seen in the finest instruments. The following double stars should also be easily seen by aid of a three-inch aperture, with a power of about eighty diameters.

α, Piscium.
Polaris.
λ, Arietis.
α, Geminorum.
λ, Leonis.
ϱ, Herculis.
μ, Draconis.
ζ, Ursæ Majoris.
ξ, Cassiopeiæ.

Another very good test for instrumental defects is a star of the second magnitude, as any imperfection is revealed by the star's disc being surrounded with numerous rays. If these are equally distributed round the central disc, the fault belongs to the object-glass, and cannot be remedied; but if seen only on one side, then the large lens is not truly adjusted, and may be made so by unscrewing the cell in which it is contained.

Though it may not at first seem so, a suitable stand is of the greatest importance, for it not unfrequently happens that by means of a defective stand, a good instrument is rendered nearly useless. Stability of structure is the first consideration that should be given in the choice of an instrument; as it is of vastly more importance than appearance. Without steadiness it is impossible to obtain good views, even with a perfect object-glass; while without vibration an indifferent instrument may be employed with advantage. With a telescope less than one inch in diameter, the French astronomer Lacialle determined the positions of no less than nearly 10,000 southern stars, but his instrument was firmly mounted.

The simplest form of stand suitable for a telescope about the same size as that above described, is what is known as the "pillar-and-claw" stand (*Fig.* 41). By means of this stand two motions can be imparted to the telescope, one in a vertical direction, or in altitude; the other horizontally, or in azimuth. The pivots on which these two movements are made, ought to be sufficiently close so as to retain the telescope in any position, and at the same time smooth enough to enable the instrument to be moved without jerking. In the more expensive stands of this form, several sliding rods, fitted with a rack-work, are attached to the base of the pillar, by means of which the instrument can be easily moved in altitude. Sometimes, too, a screw movement is provided in azimuth, which adds greatly to the ease of management of the telescope. This type of stand can be conveniently used at an open window, by being placed on a small table. If, however, access be obtained to a garden, a taller stand is necessary. For this purpose a light tripod, or garden stand, is often provided, by means of which the telescope can be more advantageously employed in the open air. If such a tripod be placed so that one of the legs points as nearly as possible towards the elevated Pole of the heavens (*i.e.*, the North Pole in the Northern, and the South Pole in the Southern Hemisphere), then by gradually pulling out that leg till the vertical axis of the telescope points approximately to that Pole, a serviceable makeshift for an equatorially-mounted instrument will be obtained, by means of which stars can be much more readily followed, than if the axis of the instrument be kept upright.

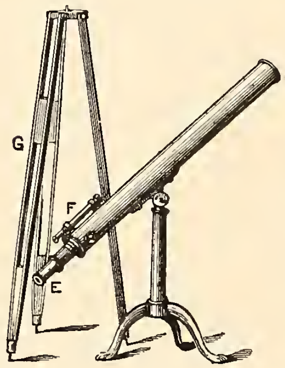


FIG. 41. THE "PILLAR AND CLAW" STAND.
F, Finder; *E*, Eye-piece; *G*, Garden or Tall Stand.

One of the most important additions to such an instrument is a *Finder*, or a very small telescope fixed on the tube of the large one, in such a manner that its axis lies parallel with that of the large instrument. In the focus of the object-glass of the finder, two wires are placed crossing each other at right angles. By means of adjusting screws, their crossing-point can be made to coincide with the centre of the field of view of the large telescope. The finder having but a very low magnifying power, it accordingly takes in a considerable part of the heavens, and therefore the object to be viewed can be found in its field without difficulty; and when once obtained is, by moving the telescope, simply brought to the centre of the cross hairs, when it will be seen in the field of view of the large instrument.

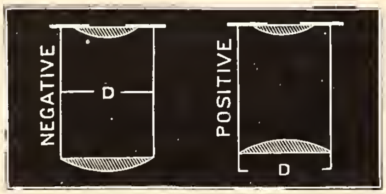


FIG. 42. EYE-PIECES.
D, Diaphragm.

Generally, small astronomical telescopes are supplied with several eye-pieces, which are of two kinds, negative and positive. The former is often called the achromatic, or Huyghenian; the latter, the Ramsden, or positive eye-piece. The Huyghenian consists of two plano-convex lenses, placed at a distance from each other equal to one-half the sum of their focal lengths, and with their flat sides directed towards the eye. In order to secure the best possible definition with this form of eye-piece, the focal lengths of the lenses ought to be in the proportion of three to one (*see Fig.* 42). In the positive eye-piece the focal lengths of the component lenses are nearly equal, and their curved sides are turned towards each other as represented in Fig. 42. For low powers and flat fields, the positive eye-piece may be employed with advantage, but as it is not perfectly achromatic, the negative eye-piece is used instead for the higher powers.

In commencing observations with a telescope, it is advisable that low powers should be first employed. These may be gradually increased until the limit governed by the aperture, and sometimes by the conditions of the atmosphere, is reached. The former is regulated very much by the object to be viewed, as the fainter it is, the less magnifying it will stand. For comets and nebulæ, a higher power than about twenty on a three-inch telescope ought not to be employed, as in this case the greatest space-penetrating power that the instrument is capable of giving is required. For viewing the planets, all powers up to about sixty to each inch of aperture can be used, or not over 200 diameters for a three-inch object-glass. When observing double stars, a much higher proportion can often with advantage be applied, or as high as 100 per inch of aperture. In viewing these most interesting objects, a complete list of which is inserted along with the star charts at the end of the volume, it must be borne in mind that the separating power of an object-lens depends entirely on its diameter. The dividing power of telescopes of different sizes are as follows:—

Diameter of telescope in inches,	1	1½	2	2½	3	3½	4	5	6	7	8	9	10
Will divide in seconds of arc, .	4·5	3·9	2·3	1·8	1·5	1·3	1·1	0·9	0·8	0·7	0·6	0·5	0·4

In viewing exceedingly close double stars, it is highly necessary that the telescope should be accurately focussed. In order to do this with the utmost delicacy, the focus ought to be adjusted on a star known to be single, and of about the same magnitude and altitude as the double star to be observed. A good deal, too, depends on the state of the atmosphere, as it is only when the air is very steady that the finest views can be obtained. After sudden changes of temperature the air is usually very unsteady, and unfavourable for observation; while on those nights when the atmosphere contains large quantities of moisture, the definition of objects is finest. Very often a slight haze takes the glare off bright objects, and enables a good deal of detail to be seen. In viewing the sun, care must be taken not to do so without proper protection. With instruments smaller than four inches in diameter, a dense neutral-tinted glass screwed over the eye-piece is all that is required; but with larger telescopes this would not be sufficient. In this case a specially constructed solar eye-piece is necessary, by the use of which, only a very small quantity of the light from the object-glass passes through the eye-lens.

In conclusion, the encouraging words of the Council of the Royal Astronomical Society should be remembered, that "every one who possesses an instrument has the power to mark out for himself a useful and honourable occupation for leisure hours, in which his labour shall be really valuable, if duly registered."

CHAPTER X.

EXPLANATION OF THE STAR CHARTS, ETC.

"Thereon were figured earth, and sky, and sea,
The ever circling sun, and full orb'd moon,
And all the signs that crown the vault of heav'n;
Pleiads and Hyads, and Orion's might,
And Arctos, call'd the Wain."—*Homer.*

As mentioned in Chapter IX., the first accurate star catalogue was constructed by Hipparchus in the year 128 B.C. This contained the positions of 1022 stars, which were afterwards revised by Ptolemy, and reduced by him to the epoch of 137 A.D. The positions of the stars in this celebrated catalogue were, as already stated, determined by means of the astrolabe at different distances from the meridian, a method which is totally different from the modern one of meridional observations. At present, we have found, the positions of celestial objects are determined by means of the transit circle, and sidereal clock. From the instant of meridian passage, the right ascension is known, as it is simply the distance in time, as indicated by the sidereal clock, from the first point of Aries, measured on the equator; while the declination, or distance in degrees from the equator, measured northwards and southwards, is determined by the altitude of the object, as indicated on the large graduated circle attached to the axis of the instrument.

By means of these two important celestial co-ordinates, which correspond to the geographical co-ordinates of longitude and latitude, the position that each object occupies in the heavens is accurately fixed, and, at the same time, identified irrespective of its name or symbol. Before the time of Hipparchus, or the time when the positions of stars were first accurately determined with respect to some part of the star-sphere, such as the ecliptic or the equator, the various orbs were identified solely by the position they occupied in the group or constellation to which they belonged. Accordingly, the more numerous the constellations into which the heavens was divided, and the more accurately these were defined, the easier could the stars be identified. Though the star-sphere of the ancients probably contained a great many constellations, Ptolemy, in his celebrated work, the *Almegest*, published about the year 150 A.D., only mentions forty-eight of them. These are known as the old constellations, most of which were familiar to Eudoxus, and are mentioned in Aratos as having been known at a very remote age (*see Chapter I.*). These constellations, as given in the Table on the opposite page, were, till within the last three hundred years, the only ones employed in dividing the stars into groups. Tycho was the first, in comparatively recent times, to invent new constellations, and this soon led other astronomers to carry out the idea to an absurd extent. The modern constellations, and the dates of their invention, are given in the Table, but many of them are not now used by astronomers, only the more important having been retained.

DESIGNATION OF INDIVIDUAL STARS.

Previous to the time of Bayer, the individual stars were identified by the positions they occupied in the constellations the brighter ones receiving special names to accurately denote this position, as for example *Rás-*

THE OLDEST KNOWN CONSTELLATIONS.

NORTHERN CONSTELLATIONS.

ANDROMEDA,	The Chained Lady.	HERCULES,	The Kneeling Man.
AQUILA,	The Eagle.	LYRA,	The Harp.
AURIGA,	The Charioteer.	OPHIUCHUS,	The Serpent-Bearer.
BOÖTES,	The Herdsman.	PEGASUS,	The Flying Horse.
CASSIOPEIA,	The Lady in her Chair.	PERSEUS,	The Rescuer.
CEPHEUS,	King Cepheus.	SAGITTA,	The Arrow.
CORONA BOREALIS,	The Northern Crown.	SERPENS,	The Serpent.
CYGNUS,	The Swan.	TRIANGULUM,	The Triangle.
DELPHINUS,	The Dolphin.	URSA MAJOR,	The Great Bear.
DRACO,	The Dragon.	URSA MINOR,	The Little Bear.
EQUULEUS,	The Little Horse.		

SOUTHERN CONSTELLATIONS.

ARA,	The Altar.	CRATER,	The Cup.
ARGO,	The Ship Argo.	ERIDANUS,	The River.
CANIS MAJOR,	The Great Dog.	HYDRA,	The Snake.
CANIS MINOR,	The Little Dog.	LEPUS,	The Hare.
CENTAURUS,	The Centaur.	LUPUS,	The Wolf.
CETUS,	The Sea Monster.	ORION,	The Hunter.
CORONA AUSTRALIS,	The Southern Crown.	PISCIS AUSTRALIS,	The Southern Fish.
CORVUS,	The Crow.		

ZODIACAL CONSTELLATIONS.

ARIES,	The Ram.	LIBRA,	The Balance.
TAURUS,	The Bull.	SCORPIO,	The Scorpion.
GEMINI,	The Twins.	SAGITTARIUS,	The Archer.
CANCER,	The Crab.	CAPRICORNUS,	The Goat.
LEO,	The Lion.	AQUARIUS,	The Water-Bearer.
VIRGO,	The Virgin.	PISCES,	The Fishes.

THE MODERN CONSTELLATIONS.

Name of Constellation.	*By whom Invented.*	*Date when added.*	*Name of Constellation.*	*By whom Invented.*	*Date when added.*
ANTINOUS,	Tycho Brahé,	1603 A.D.	COR CAROLI,	Flamsteed,	1725 A.D.
COMA BERENICES,	,,	,,	MONS MAENALUS,	,,	,,
APIS,	Bayer,	1604	ANTLIA,	La Caille,	1752
AVIS INDICA,	,,	,,	CAEDA SCULPTORIS,	,,	,,
CHAMÆLEON,	,,	,,	CIRCINUS,	,,	,,
DORADO,	,,	,,	FORNAX,	,,	,,
GRUS,	,,	,,	HOROLOGIUM,	,,	,,
HYDRUS,	,,	,,	EQUULEUS PICTORIS,	,,	,,
INDUS,	,,	,,	MICROSCOPIUM,	,,	,,
PHOENIX,	,,	,,	MONS MENSAE,	,,	,,
PISCIS VOLANS,	,,	,,	NORMA,	,,	,,
PAVO,	,,	,,	OCTANS,	,,	,,
TOUCAN,	,,	,,	RETICULUM,	,,	,,
TRIANGULUM AUSTRALE,	,,	,,	SCULPTOR,	,,	,,
CAMELOPARDALIS,	Helvelius,	1690	PIXIS NAUTICA,	,,	,,
CANES VENATICI,	,,	,,	TELESCOPIUM,	,,	,,
CERBERUS,	,,	,,	SOLITARIUS,	Le Monnier,	1776
LACERTA,	,,	,,	TARANDUS,	,,	,,
LEO MINOR,	,,	,,	MESSIER,	Lalande,	,,
LYNX,	,,	,,	TAURUS PONIATOWSKII,	Poczobut,	1777
MONOCEROS,	,,	,,	FELIS,	Bode,	1800
SUCUTUM,	,,	,,	GLOBUS AËROSTATICUS,	,,	,,
SEXTANS,	,,	,,	HONORES FREDERICI,	,,	,,
VULPECULA,	,,	,,	LOCHIUM FUNIS,	,,	,,
COLUMBA NOACHI,	Royer,	1679	MACHINA ELECTRICA,	,,	,,
CRUX,	,,	,,	OFFICINA TYPOGRAPHICA,	,,	,,
FLEUR-DE-LIS,	,,	,,	QUADRANS MURALIS,	,,	,,
NUBIS MAJOR,	,,	,,	SCEPTRUM BRANDENBURGICUM,	,,	,,
NUBIS MINOR,	,,	,,	TELESCOPIUM HERSCHELLII,	,,	
ROBUR CAROLI,	Halley,	1680			

al-gáthi, the Kneeler's Head. By this means nearly every star could be described, for even those which were situated outside of the constellation were designated in a similar manner by their alignments with the brighter stars of the surrounding groups. In 1603 this cumbersome method was superseded by the elegant invention of Bayer, which has been found so convenient for the more important stars that it still remains in general use. This invention consisted in calling the stars in each constellation after some letter in the Greek alphabet, the sequence of the letters depending on the position of the stars in the constellation figure. Thus the seven stars in the "Plough," beginning with the one nearest to the pole, are designated α, β, γ, δ, ε, ζ, η. In this manner the stars in each constellation are identified, until all the Greek letters are exhausted, when Roman letters are employed in continuation; and, finally, when these fail, numbers are assigned instead. Flamsteed, the first Astronomer Royal at Greenwich, used numbers entirely for the stars in the constellations which he observed. Accordingly every star visible to the naked eye can be referred to, and at once identified either by a name, letter, or number, and sometimes by all of these. The principal star in Taurus, for instance, could be referred to as *Aldebaran*, α Tauri, or 87 (Flamsteed), of the same constellation; while it could also be identified by its number in some standard star catalogue, so that 1420 B.A.C. and 8639 Ll. indicates the same star, these being its number in the British Association and Lalande catalogues respectively. There are still other methods employed by modern astronomers for the purpose of identifying stars—viz., of arranging them into zones and numbering them accordingly. Piazzi adopted the method of numbering the stars according to the position they occupy in the hour of right ascension, while in the large catalogue of Argelander's, called the "Durchmusterung," which contains no less than 324,000 stars, the stars are arranged and numbered in zones of declination one degree in breadth, and therefore *Aldebaran* could further be designated, P. iv. 125, and D.M. +16° 629.

THE GREEK ALPHABET.

Letter.	Name.	Letter.	Name.	Letter.	Name.	Letter.	Name.
α	Alpha	η	Eta	ν	Nu	τ	Tau
β	Beta	θ	Theta	ξ	Xi	υ	Upsilon
γ	Gamma	ι	Iota	ο	Omicron	φ	Phi
δ	Delta	κ	Kappa	π	Pi	χ	Chi
ε	Epsilon	λ	Lambda	ρ	Rho	ψ	Psi
ζ	Zeta	μ	Mu	σ	Sigma	ω	Omega

MAGNITUDES OF STARS.

The relative amount of light which is received from a star, or its apparent brilliancy, is termed its magnitude. The scale by means of which this was first determined was invented by Hipparchus. It consisted in dividing the stars visible to the unaided eye, from the brightest to the faintest, into six classes. The small group of brightest orbs were designated stars of the first magnitude, the next in brilliancy, stars of the second magnitude, until the faintest or sixth magnitude stars were reached. As there are many stars whose brilliancy lies midway between two whole magnitudes, a finer scale was necessary, and accordingly the magnitude of the stars in the catalogues of Hipparchus and Ptolemy were further divided into thirds. For a considerable time after Ptolemy, the more accurate method of arranging the stars into thirds of magnitude was abandoned, and it was only resumed in comparatively modern times. This method, which was adopted by Flamsteed, Argelander, Heis, and others, is as delicate a sub-division of stellar lights as the unaided eye is capable of distinguishing. It consists in first recording the stars belonging to the different whole magnitudes, then noting the other stars which are nearest in brightness to these. The various magnitudes and thirds of a magnitude are indicated as follows, the magnitude to which the star is nearest being placed first:—

Whole magnitudes, . . .	1	2	3	4	5	6
One-third of a magnitude, . . .	1,2	2,3	3,4	4,5	5,6	6,7
Two-thirds of a magnitude, . .	2,1	3,2	4,3	5,4	6,5	7,6

Accordingly 1,2 means $1\frac{1}{3}$; 2,1, $1\frac{2}{3}$, &c.

Since the employment of instruments for the determination of stellar magnitudes this scale of thirds has been discarded, and the more minute system of decimals used instead. In the modern determinations, therefore, the magnitudes of stars are given to the nearest *tenth*, the fractional part increasing as the brightness of the star diminishes; so that 1·2 magnitude indicates that the particular star is slightly brighter than one with a magnitude of 1·3. Similarly, a star whose magnitude is indicated by 0·5 is brighter than one whose magnitude is 1·0, while the magnitude of *Sirius*, the brightest star in the heavens, is represented by *−1·4*, thereby meaning that it is more than a whole magnitude brighter than a star with a magnitude of 0·0. The number of stars in the various magnitudes visible to the unaided eye are as follows:—

MAGNITUDE.	NUMBER OF STARS.	MAGNITUDE.	NUMBER OF STARS.
0·0 to 1·5	21	4·1 to 4·5	316
1·6 „ 2·0	27	4·6 „ 5·0	446
2·1 „ 2·5	41	5·1 „ 5·5	937
2·6 „ 3·0	71	5·6 „ 6·0	1884
3·1 „ 3·5	138	6·1 „ 6·5	2908
3·6 „ 4·0	195		Total, 6994

STAR CHARTS.

The very ancient astronomers were doubtless accustomed to depict the appearance of the starry heavens either on maps or on the surface of spheres of stone or metal. The earliest known instance of the constellations having been represented in this manner is the celebrated sphere of Eudoxos, constructed four centuries before our era (*see Fig.* 1). On this celestial globe, as on the modern ones, the constellations are reversed, as the eye of the observer is supposed to be placed in the centre of the sphere. This method of depicting the heavens was also adopted in the construction of star charts, and it was only as recent as the year 1603 that the more convenient and natural plan of representing the actual appearance of the star groups as seen from the earth, was adopted by Bayer. By this means the celestial maps could be compared directly with the starry sky, which had a considerable advantage over the fictitious outer surface of the imaginary celestial sphere.

This is the method adopted in the star charts inserted at the end of the volume. The projection which has been employed in their construction is the one best suited to represent the appearance of the various star groups with the least possible distortion. By means of the twelve maps, the complete celestial sphere is depicted on a sufficiently large scale to enable the observer to readily identify even the faintest star indicated. To ensure the identification of objects being carried out with the greatest amount of ease, and to prevent the confusion which often arises when a constellation happens to be situated near the edge of a chart, each map has been constructed so as to represent more than a twelfth portion of the star-sphere. Accordingly, those constellations placed round the sides of the maps are indicated on at least two charts. This overlapping is especially valuable for clearly depicting the equatorial regions, as by it a zone extending to ten degrees on either side of the equator is doubly represented.

In constructing these charts, the constellation figures were not inserted, as they only tend to confuse the observer, without increasing the value of the maps. The positions, however, which the constellations occupy are clearly indicated by the boundary lines which enclose the stars belonging to the different groups. Only the more important of the constellations have been inserted, as many of those added within recent times are not recognised by astronomers. An alphabetical list of those used in the charts, with the number of stars in each, is given on pages 118 and 119; by means of which the number of the chart or circular map in which a constellation will be found, can be readily obtained.

In these charts, which contain more than 6000 objects, the stars are designated in the usual manner. Where a star has a Greek or Roman letter, it has been inserted, and if not, the Flamsteed number has been affixed instead. For the use of those desiring the accurate position of a star, the Table of Right Ascensions and Declinations of stars for the year 1890 is given on pages 127 to 135. The more important variable stars, double stars, nebulæ, and star clusters are also inserted, which it is hoped will be of some value to those possessing small telescopes. The manner in which these objects are indicated is represented in Fig. 43. Accompanying the maps, a description will be found of the more interesting celestial objects visible with a telescope of moderate power.

In using the maps the small circular charts will be of the greatest assistance, as by their aid the position which a particular constellation occupies with respect to the horizon can be ascertained for any required time. The circular maps are so constructed that they accurately represent the actual appearance of the heavens in the northern and southern hemispheres for certain times. Accordingly, the exact positions of the various constellations for any date and hour can be at once found by examining Tables 5 and 6 on pages 122 to 125. From these, the corresponding circular chart is ascertained which represents the appearance of the star-sphere for the required time, and by means of the figures indicated in these maps, the large chart which corresponds to the particular part of the sky which it is desired to examine is also revealed. If, on the other hand, the time is required when a certain group can be seen, Table 1 on pages 118 and 119 will give the information. By its aid the circular chart which contains the constellation can at once be found; when by referring to the particular map the time at which it is visible is indicated.

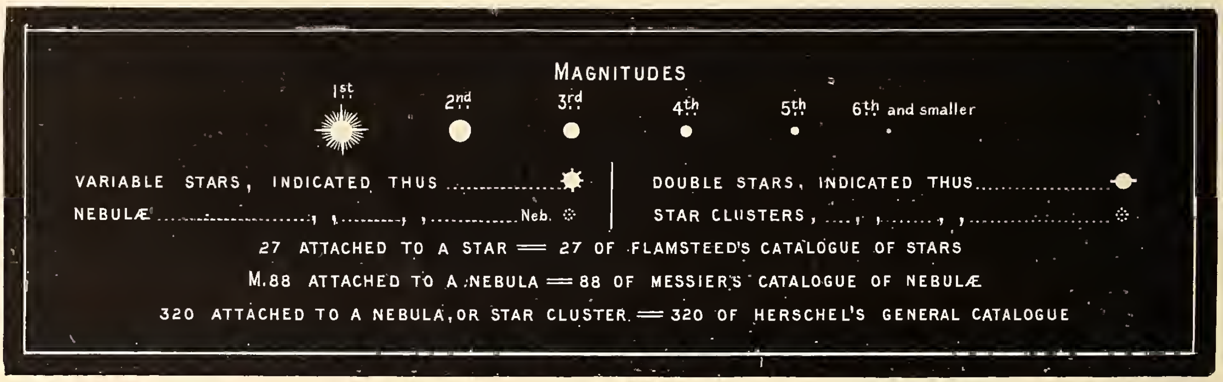

MAGNITUDES
1st
2nd
3rd
4th
5th
6th and smaller
VARIABLE STARS, INDICATED THUS
DOUBLE STARS, INDICATED THUS
NEBULÆ
Neb.
STAR CLUSTERS
27 ATTACHED TO A STAR = 27 OF FLAMSTEED'S CATALOGUE OF STARS
M.88 ATTACHED TO A NEBULA = 88 OF MESSIER'S CATALOGUE OF NEBULÆ
320 ATTACHED TO A NEBULA, OR STAR CLUSTER. = 320 OF HERSCHEL'S GENERAL CATALOGUE

Fig. 43.—Explanation of the Star Charts.

The large scale plate, Chart 13, has been constructed so as to give a complete view of the zodiacal and equatorial regions, and will thus be of great use for those who desire to follow the movements of the more conspicuous planets among the stars. This will be greatly facilitated by the heliocentric paths of the planets being indicated, or their apparent paths as viewed from the sun. By means of the right ascension and declination lines the position (obtained from an almanac) of a planet, comet, or other heavenly body, can be marked on the chart, and by noting the surrounding stars, easily identified.

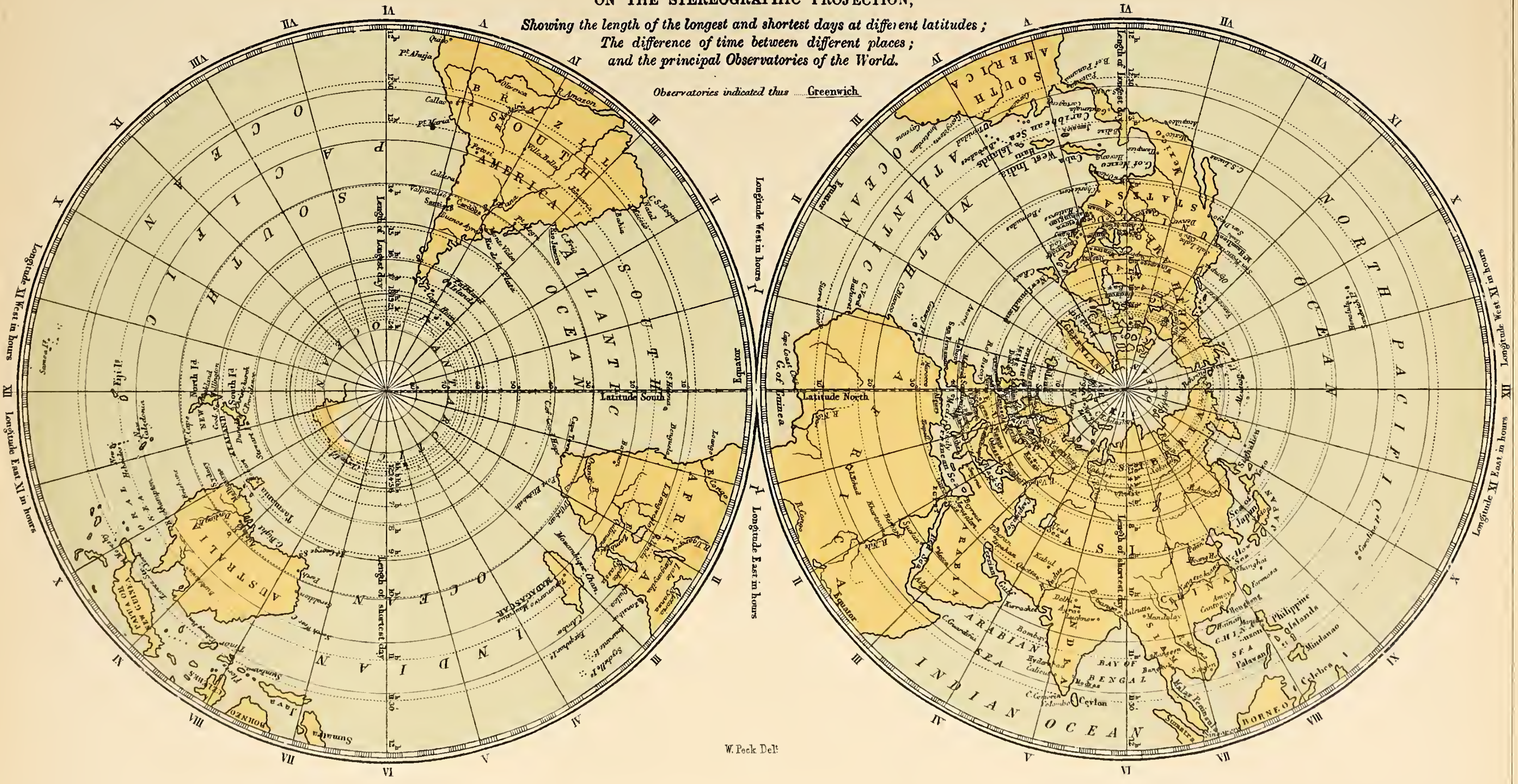
As it is often desirable to ascertain the time of sunrise and sunset, and the approximate duration of twilight, in order to know when the faintest stars can be seen, the Tables inserted on pages 120 and 121 have been constructed. By means of these Tables this information can be found without much difficulty, for any part of the globe, and any time of the year. From Table 2, in a line with the required *date,*

CHART OF THE WORLD,

ON THE STEREOGRAPHIC PROJECTION,

Showing the length of the longest and shortest days at different latitudes;
The difference of time between different places;
and the principal Observatories of the World.

Observatories indicated thus ...... Greenwich


Longitude XI West in hours
XII
Longitude East XI in hours
Longitude West in hours I
I Longitude East in hours
Longitude West XI in hours
Longitude XI East in hours
Length of Longest day
Length of shortest day
Latitude South
Latitude North
Equator
SOUTH PACIFIC OCEAN
SOUTH ATLANTIC OCEAN
INDIAN OCEAN
ANTARCTIC
SOUTH AMERICA
BRAZIL
AFRICA
AUSTRALIA
NEW ZEALAND
MADAGASCAR
NORTH PACIFIC OCEAN
NORTH ATLANTIC OCEAN
NORTH AMERICA
UNITED STATES
GREENLAND
EUROPE
ASIA
AFRICA
ARABIA
INDIA
CHINA
SIAM
JAPAN
ARABIAN SEA
BAY OF BENGAL
Caribbean Sea
West India Islands
Mediterranean Sea
G. of Guinea
BORNEO
Sumatra
Java
Philippine Islands
Ceylon

W. Peck Delt

Engraved by Archibald & Peck Edinr

Gall & Inglis, Edinburgh.

and in the column indicated by the particular *latitude* of the place of observation, the hours and minutes of semi-diurnal arc will be found. This is equal to the *apparent* time of *sunset*, or of sunrise if subtracted from twelve hours. To find the true local *mean* time, the correction of equation of time in Table 3 is to be applied to the apparent time of sunrise and sunset already ascertained. Then, lastly, the duration of twilight can be found from Table 4, which, when applied to the time of sunrise and sunset, gives the ending and beginning, respectively, of total darkness.

Thus, for example, suppose it is desired to know the time of sunrise and sunset on 22nd October, for north latitude 55 degrees. Take from Table 2 the semi-diurnal arc corresponding to this date and latitude. This will be found to be 4h. 56m., which is equal to the apparent time of sunset for the date mentioned; or, if subtracted from 12h., gives 7h. 4m. for the apparent time of sunrise. To find the equivalent mean time, the equation of time found in Table 3 is to be applied. For the above date this is — 15m.; so that this quantity has to be subtracted from the apparent times already ascertained, when the true *local mean* time of sun-rising and sun-setting, become respectively, 6h. 49 A.M., and 4h. 43m. P.M. Lastly, from Table 4, the duration of twilight is found to be 2h. 10m., which, when subtracted from the time of sunrise, and added to the time of sunset, gives 4h. 39m. A.M., and 6h. 51m., P.M. for the time of the ending (in the morning) and beginning (in the evening) of total darkness. For ascertaining the time of a *star's* rising, setting, and meridian passage, see Tables 7 and 8, which have been constructed to give this information with the least amount of trouble.

As above mentioned, the times of sunrise and sunset thus determined are according to *local* mean time, or only for the time at the place for which they have been calculated. If, therefore, these local times are required to be converted into the mean time of any other meridian (as into Greenwich mean time), then the difference of longitude in time between the two places must be applied. If, for instance, the place for which the time of sunrise and sunset be required, is to the west of the meridian of the place whose time is employed (as in the case of Edinburgh from Greenwich), then the difference of longitude has to be added to the local time; and if to the east, subtracted. From the Chart of the World, Plate 20, the difference of longitude in time between any two meridians, as well as the latitude of any place, can be ascertained. This Plate has been specially constructed on the Stereographic Projection, as it is one which recommends itself to the student for the many elegant and valuable properties which it possesses. On this projection, as is well known, all circles, great or small, with the exception of those which pass directly through the centre of projection, are projected into true circles; while all intersecting lines on the sphere are projected into lines intersecting on the Chart at exactly the same angle. Accordingly, in determining on the Chart the position of any circle of the sphere, unlike several other projections, only three points require to be projected, and the circle drawn through these points is the true projection of the circle.

TABLE 1.—LIST OF THE CONSTELLATIONS INDICATED IN THE STAR CHARTS,

And the Principal Charts in which each occurs.

(*Note.—In the third Column,* "*Nos.* 8 *to* 3" *means Nos.* 8, 9, 10, 11, 12, 1, 2, 3; "23 *to* 14" *means* 23, 24, 13, 14; *and similarly for other numbers*).

Name of Constellation.	*Charts in which the Constellation is inserted.*		Number of Stars in the Constellation.	
	Large Star Charts.	Small Circular Maps. *N. Hemisphere.* *S. Hemisphere.*	*Shown in the Charts.*	*In Flamsteed's Catalogue.*
	Nos.	Nos.		
Andromeda, . .	2, 13	8 to 3 and 22 to 13	95	66
Antlia, . . .	9	22 to 18	28	3
Apus, ...	12	13 to 24	22	11
Aquarius, . . .	11, 13	8 to 12 and 20 to 24	117	108
Aquila, . . .	6, 10, 11, 13	6 to 11	91	71
Ara, ...	10, 12	13 to 24	62	9
Argo, (Carina, Malus, Puppis, Vela), .	8, 12	22 to 18	363	64
Aries, . . .	2, 13	9 to 3 and 23 to 14	52	66
Auriga, . . .	3, 13	10 to 5 and 13 to 14	72	66
Boötes, . . .	5, 13	3 to 9 and 17 to 20	107	54
Cœlum, . . .	7	22 to 17	25	...
Camelopardalis, .	1	1 to 12	117	58
Cancer, . . .	4, 13	1 to 6 and 13 to 17	62	83
Canes Venatici, .	5	1 to 12	40	25
Canis Major, . .	8	1 to 3 and 23 to 17	73	31
Canis Minor, . .	4, 13	11 to 5 and 13 to 17	25	14
Capricornus, . .	11, 13	8 to 10 and 19 to 24	60	51
Cassiopeia, . .	1	1 to 12	101	55
Centaurus, . .	9, 12, and 13	14 to 22	184	35
Cepheus, . . .	1	1 to 12	97	35
Cetus, . . .	7, 13	10 to 2 and 21 to 13	108	97
Chamæleon, . .	12	13 to 24	36	10
Circinus, . . .	12	13 to 24	11	4
Columba, . . .	8	22 to 17	65	10
Coma Bernices, . .	5	3 to 8 and 16 to 19	50	43
Corona Australis, .	10	17 to 23	26	12
Corona Borealis, .	5	17 to 20	29	21
Corvus, . . .	9, 13	4 to 6 and 14 to 19	12	9
Crater, . . .	9, 13	3 to 6 and 14 to 19	13	31
Crux, ...	12	13 to 24	16	6
Cygnus, . . .	6	5 to 1 and 20 to 22	159	81
Delphinus, . .	6	7 to 12 and 19 to 23	17	18
Dorado, . . .	8	13 to 24	55	7
Draco, . . .	1	1 to 12	162	80
Equuleus, . . .	6, 13	7 to 12 and 19 to 23	11	10
Eridanus, . . .	7, 13	11 to 2 and 21 to 16	148	84
Fornax, . . .	7	21 to 16	58	14
Gemini, . . .	3, 13	11 to 5 and 13 to 16	64	85
Grus, ...	12	13 to 24	68	13
Hercules, . . .	6, 13	4 to 10 and 18 to 20	140	113
Horologium, . .	12, 7	13 to 24	50	12

LIST OF THE CONSTELLATIONS INDICATED IN THE STAR CHARTS—*continued.*

NAME OF CONSTELLATION.	*CHARTS IN WHICH THE CONSTELLATION IS INSERTED.*		NUMBER OF STARS IN THE CONSTELLATION.	
	LARGE STAR CHARTS.	SMALL CIRCULAR MAPS. *N. Hemisphere.* *S. Hemisphere.*	*Shown in the Charts.*	*In Flamsteed's Catalogue.*
	Nos.	Nos.		
HYDRA, ...	8, 9, 13	2 to 6 and 13 to 18	118	60
HYDRUS, ...	12	13 to 24	57	10
INDUS, ...	12	13 to 24	61	12
LACERTA, . . .	2	5 to 1	36	16
LEO, ...	4, 13	2 to 7 and 15 to 18	94	95
LEO MINOR, . .	4, 13	1 to 7 and 15 to 18	32	53
LEPUS, ...	8	11 to 3 and 23 to 17	31	19
LIBRA, ...	10, 13	5 to 8 and 16 to 21	53	51
LUPUS, ...	10, 12, 13	14 to 22	61	24
LYNX, ...	4, 13	1 to 12	46	44
LYRA, ...	6	5 to 12 and 19 to 21	43	22
MENSA, ...	12	13 to 24	28	30
MICROSCOPIUM, . .	11, 13	13 to 24	15	10
MONOCEROS, . .	8, 13	13 to 24	46	31
MUSCA, ...	12	13 to 24	35	4
NORMA, ...	10, 12	14 to 22	48	12
OCTANS, ...	12	13 to 24	55	43
OPHIUCHUS, . .	10, 6, 13	5 to 9 and 17 to 21	93	74
ORION, ...	3, 13	11 to 4 and 23 to 16	83	78
PAVO, ...	12	13 to 24	106	14
PEGASUS, . . .	2, 13	8 to 1 and 21 to 24	94	89
PERSEUS, . . .	3, 13	9 to 5 and 24 and 13	70	89
PHŒNIX, . . .	12, 7	13 to 24	86	13
PICTOR, ...	12, 8	22 to 17	37	16
PISCES, ...	2, 13	9 to 2 and 22 to 13	109	113
PISCIS AUSTRALIS, .	11, 13	10 to 11 and 19 to 13	27	24
RETICULUM, . .	12	13 to 24	26	10
SAGITTA, . . .	6	6 to 12	20	18
SAGITTARIUS, . .	10, 13	7 to 9 and 17 to 23	115	69
SCORPIO, . . .	10, 13	6 to 8 and 16 to 22	90	44
SCULPTOR, . . .	7, 13	21 to 13	52	12
SERPENS, . . .	5, 6, 13	5 to 10 and 17 to 21	59	64
SEXTANS, . . .	9, 13	2 to 7 and 15 to 18	30	41
TAURUS, ...	3, 13	10 to 4 and 23 to 15	127	141
TELESCOPIUM, . .	10	17 to 23	19	9
TOUCAN, . . .	12	13 to 24	78	9
TRIANGULUM, . .	2, 13	9 to 3 and 23 to 13	27	11
TRIANGULUM AUSTRALE, .	12	13 to 24	14	5
URSA MAJOR, . .	1, 13	1 to 12	122	87
URSA MINOR, . .	1	1 to 12	40	24
VIRGO, ...	5, 9, 13	3 to 7 and 15 to 19	139	110
VOLANS, ...	12	13 to 24	28	8
VULPECULA, . .	6	6 to 12	35	37

TABLE 2.

APPARENT TIME OF SUNRISE AND SUNSET AT DIFFERENT LATITUDES.

The figures in the columns give the time of Sunset on the dates mentioned at the sides. To find the time of Sunrise, subtract the time of Sunset from 12 hours; the answer gives the time of Sunrise. (*See p. 117.*)

DATES FOR NORTH LATITUDE.				TIME OF SUNSET FOR LATITUDE 0°		10°		20°		30°		40°		45°		50°		55°		60°		DATES FOR SOUTH LATITUDE.			
				h.	m.	h.	m.	h.	m.	h.	m.	h.	m.	h.	m.	h.	m.	h.	m.	h.	m.				
December	21	December	21	6	0	5	42	5	23	5	2	4	34	4	17	3	55	3	24	2	45	June	21	June	21
January	1		11	6	0	5	43	5	24	5	3	4	37	4	20	3	58	3	31	2	51	July	2		10
	9		2	6	0	5	44	5	26	5	6	4	41	4	25	4	5	3	39	3	2		11	May	31
	15	November	26	6	0	5	44	5	28	5	9	4	45	4	30	4	11	3	47	3	13		18		25
	20		21	6	0	5	45	5	30	5	11	4	49	4	35	4	17	3	55	3	24		23		20
	24		17	6	0	5	46	5	31	5	14	4	53	4	39	4	23	4	2	3	34		28		16
	28		13	6	0	5	47	5	33	5	17	4	57	4	44	4	29	4	10	3	43	August	1		11
February	1		9	6	0	5	48	5	34	5	19	5	1	4	49	4	35	4	16	3	52		5		8
	4		6	6	0	5	48	5	36	5	22	5	4	4	54	4	40	4	23	4	1		8		4
	8		3	6	0	5	49	5	38	5	24	5	8	4	58	4	46	4	30	4	9		12		1
	11	October	30	6	0	5	50	5	39	5	27	5	12	5	2	4	51	4	37	4	18		15	April	27
	14		27	6	0	5	51	5	41	5	29	5	15	5	6	4	56	4	43	4	26		18		24
	17		25	6	0	5	51	5	42	5	32	5	19	5	11	5	1	4	50	4	34		21		21
	19		22	6	0	5	52	5	44	5	34	5	22	5	15	5	6	4	56	4	41		24		18
	22		19	6	0	5	53	5	45	5	37	5	26	5	20	5	11	5	2	4	49		27		15
	25		16	6	0	5	54	5	47	5	39	5	29	5	24	5	16	5	8	4	56		30		13
	28		13	6	0	5	54	5	48	5	41	5	33	5	28	5	21	5	13	5	4	September	2		10
March	2		11	6	0	5	55	5	50	5	44	5	36	5	32	5	26	5	19	5	11		4		7
	5		8	6	0	5	56	5	51	5	46	5	40	5	36	5	31	5	25	5	18		7		5
	7		5	6	0	5	56	5	53	5	48	5	43	5	40	5	36	5	31	5	25		10		2
	10		3	6	0	5	57	5	54	5	51	5	47	5	44	5	41	5	37	5	32		12	March	30
	13	September	30	6	0	5	58	5	56	5	53	5	50	5	48	5	46	5	42	5	39		15		28
	15		28	6	0	5	59	5	57	5	55	5	53	5	52	5	50	5	48	5	46		17		25
	18		25	6	0	5	59	5	59	5	58	5	57	5	56	5	55	5	54	5	53		20		23
	20		22	6	0	6	0	6	0	6	0	6	0	6	0	6	0	6	0	6	0		22		20
	23		20	6	0	6	1	6	1	6	2	6	3	6	4	6	5	6	6	6	7		25		18
	25		17	6	0	6	1	6	3	6	5	6	7	6	8	6	10	6	11	6	14		28		15
	28		15	6	0	6	2	6	4	6	7	6	10	6	12	6	14	6	17	6	21		30		13
	30		12	6	0	6	3	6	6	6	9	6	13	6	16	6	19	6	23	6	28	October	3		10
April	2		10	6	0	6	4	6	7	6	12	6	17	6	20	6	24	6	29	6	35		5		7
	5		7	6	0	6	4	6	9	6	14	6	20	6	24	6	29	6	35	6	42		8		5
	7		4	6	0	6	5	6	10	6	16	6	24	6	28	6	34	6	40	6	49		11		2
	10		2	6	0	6	6	6	12	6	19	6	27	6	32	6	39	6	46	6	56		13	February	28
	13	August	30	6	0	6	6	6	13	6	21	6	31	6	36	6	44	6	52	7	4		16		25
	15		27	6	0	6	7	6	15	6	23	6	34	6	41	6	49	6	58	7	11		19		22
	18		24	6	0	6	8	6	16	6	26	6	38	6	45	6	54	7	4	7	19		22		19
	21		21	6	0	6	9	6	18	6	28	6	41	6	49	6	59	7	11	7	26		25		17
	24		18	6	0	6	9	6	19	6	31	6	45	6	53	7	4	7	17	7	34		27		14
	27		15	6	0	6	10	6	21	6	33	6	48	6	58	7	9	7	23	7	42		30		11
May	1		12	6	0	6	11	6	22	6	36	6	52	7	2	7	14	7	30	7	51	November	3		8
	4		8	6	0	6	12	6	24	6	38	6	56	7	7	7	20	7	37	7	59		6		4
	8		5	6	0	6	12	6	26	6	41	6	59	7	11	7	25	7	44	8	0		9		1
	11		1	6	0	6	13	6	27	6	43	7	3	7	16	7	31	7	51	8	17		13	January	28
	16	July	28	6	0	6	14	6	29	6	46	7	7	7	21	7	37	7	58	8	26		17		24
	20		23	6	0	6	15	6	30	6	49	7	11	7	25	7	43	8	5	8	36		21		20
	25		18	6	0	6	16	6	32	6	51	7	15	7	30	7	49	8	13	8	47		26		15
	31		11	6	0	6	16	6	34	6	54	7	19	7	35	7	55	8	21	8	58	December	2		9
June	10		2	6	0	6	17	6	36	6	57	7	23	7	40	8	2	8	29	9	9		11		1
	21	June	21	6	0	6	18	6	36	6	58	7	25	7	43	8	5	8	33	9	15		21	December	21

TABLE 3.—EQUATION OF TIME.

On these dates the Minutes of Equation of Time are to be added to or subtracted from, as the case may be, the Apparent Time of Sunrise or Sunset as determined from Table 2. (See p. 117.)

DATE.	*Minutes*		*DATE.*	*Minutes*		*DATE.*	*Minutes*	
	To be ADDED.	*To be* SUBTRACTED.		*To be* ADDED.	*To be* SUBTRACTED.		*To be* ADDED.	*To be* SUBTRACTED.
January 1	4	...	May 14	...	4	October 3	...	11
4	5	...	28	...	3	6	...	12
6	6	...	June 4	...	2	10	...	13
8	7	...	9	...	1	14	...	14
10	8	...	14	0	0	17	...	$14^{m}\ 30^{s}$
13	9	...	19	1	...	20	...	15
16	10	...	24	2	...	27	...	16
19	11	...	29	3	...	November 9	...	16
23	12	...	July 4	4	...	16	...	15
27	13	...	10	5	...	19	...	$14^{m}\ 30^{s}$
February 3	14	...	19 to 31	6	...	21	...	14
10	$14^{m}\ 30^{s}$	...	August 2	6	...	24	...	13
26	13	...	11	5	...	27	...	12
March 3	12	...	16	4	...	30	...	11
7	11	...	21	3	...	December 3	...	10
11	10	...	25	2	...	5	...	9
15	9	...	28	1	...	8	...	8
18	8	...	September 1	0	0	10	...	7
22	7	...	4	...	1	12	...	6
25	6	...	7	...	2	14	...	5
28	5	...	10	...	3	16	...	4
April 1	4	...	13	...	4	18	...	3
4	3	...	15	...	5	20	...	2
7	2	...	18	...	6	22	...	1
11	1	...	21	...	7	24	0	0
15	0	0	24	...	8	27	1	...
20	...	1	27	...	9	29	2	...
25	...	2	30	...	10	31	3	...
30	...	3						

TABLE 4.—DURATION OF TWILIGHT AT DIFFERENT LATITUDES.

FOR NORTH LATITUDE			*LATITUDE.*	FOR SOUTH LATITUDE		
At June Solstice.	*At Equinoxes (March and Sept.).*	*At December Solstice.*		*At December Solstice.*	*At Equinoxes (Sept. and March).*	*At June Solstice.*
h. m.	h. m.	h. m.		h. m.	h. m.	h. m.
1 19	1 12	1 19	0°	1 19	1 12	1 19
1 21	1 13	1 19	10°	1 21	1 13	1 19
1 28	1 17	1 23	20°	1 28	1 17	1 23
1 41	1 24	1 30	30°	1 41	1 24	1 30
2 9	1 35	1 43	40°	2 9	1 35	1 43
2 39	1 44	1 53	45°	2 39	1 44	1 53
Twilight extends from sunset to sunrise.	1 55	2 6	50°	*Twilight extends from sunset to sunrise.*	1 55	2 6
	2 10	2 26	55°		2 10	2 26
	2 33	2 57	60°		2 33	2 57
	3 8	4 3	65°		3 8	4 3

TABLE 5.

FOR FINDING THE STARS VISIBLE IN THE NORTHERN HEMISPHERE,

AT DIFFERENT DATES AND HOURS, BY MEANS OF THE CIRCULAR MAPS.

TIME.	JANUARY				FEBRUARY				MARCH				APRIL			
	5	13	20	27	5	13	20	27	7	15	22	29	6	14	21	28
4 h. 0 m.	...	...	11	...	...	...	12	...	...	...	1	...	...	...	2	...
30 „	...	11	...	...	...	12	...	...	...	1	...	...	...	2	...	...
5 h. 0 m.	11	...	...	...	12	...	...	...	1	...	...	...	2	...	...	...
30 „	...	...	...	12	...	...	...	1	...	...	...	2	...	...	...	3
6 h. 0 m.	...	...	12	...	...	...	1	...	...	...	2	...	...	...	3	...
30 „	...	12	...	...	...	1	...	...	...	2	...	...	...	3	...	...
7 h. 0 m.	12	...	...	...	1	...	...	...	2	...	...	...	3	...	...	...
30 „	...	...	...	1	...	...	...	2	...	...	...	3	...	...	...	4
8 h. 0 m.	...	...	1	...	...	...	2	...	...	...	3	...	...	...	4	...
30 „	...	1	...	...	...	2	...	...	...	3	...	...	...	4	...	...
9 h. 0 m.	1	...	...	...	2	...	...	...	3	...	...	...	4	...	...	...
30 „	...	...	...	2	...	...	...	3	...	...	...	4	...	...	...	5
10 h. 0 m.	...	...	2	...	...	...	3	...	...	...	4	...	...	...	5	...
30 „	...	2	...	...	...	3	...	...	...	4	...	...	...	5	...	...
11 h. 0 m.	2	...	...	...	3	...	...	...	4	...	...	...	5	...	...	...
30 „	...	...	...	3	...	...	...	4	...	...	...	5	...	...	...	6
12 h. 0 m.	...	...	3	...	...	...	4	...	...	...	5	...	...	...	6	...
30 „	...	3	...	...	...	4	...	...	...	5	...	...	...	6	...	...
*13 h. 0 m.	3	...	...	...	4	...	...	...	5	...	...	...	6	...	...	...
30 „	...	...	...	4	...	...	...	5	...	...	...	6	...	...	...	7
14 h. 0 m.	...	...	4	...	...	...	5	...	...	...	6	...	...	...	7	...
30 „	...	4	...	...	...	5	...	...	...	6	...	...	...	7	...	...
15 h. 0 m.	4	...	...	...	5	...	...	...	6	...	...	...	7	...	...	...
30 „	...	...	...	5	...	...	...	6	...	...	...	7	...	...	...	8
16 h. 0 m.	...	...	5	...	...	...	6	...	...	...	7	...	...	...	8	...
30 „	...	5	...	...	...	6	...	...	...	7	...	...	...	8	...	...
17 h. 0 m.	5	...	...	...	6	...	...	...	7	...	...	...	8	...	...	...
30 „	...	...	...	6	...	...	...	7	...	...	...	8	...	...	...	9
18 h. 0 m.	...	...	6	...	...	...	7	...	...	...	8	...	...	...	9	...
30 „	...	6	...	...	...	7	...	...	...	8	...	...	...	9	...	...
19 h. 0 m.	6	...	...	...	7	...	...	...	8	...	...	...	9	...	...	...
30 „	...	...	...	7	...	...	...	8	...	...	...	9	...	...	...	10
20 h. 0 m.	...	...	7	...	...	...	8	...	...	...	9	...	...	...	10	...

TIME.	MAY				JUNE				JULY				AUGUST			
	7	15	22	29	6	14	21	28	7	15	22	29	6	14	21	28
4 h. 0 m.	...	...	3	...	...	...	4	...	...	...	5	...	...	...	6	...
30 „	...	3	...	...	...	4	...	...	...	5	...	...	...	6	...	...
5 h. 0 m.	3	...	...	...	4	...	...	...	5	...	...	...	6	...	...	...
30 „	...	...	...	4	...	...	...	5	...	...	...	6	...	...	...	7
6 h. 0 m.	...	...	4	...	...	...	5	...	...	...	6	...	...	...	7	...
30 „	...	4	...	...	...	5	...	...	...	6	...	...	...	7	...	...
7 h. 0 m.	4	...	...	...	5	...	...	...	6	...	...	...	7	...	...	...
30 „	...	...	...	5	...	...	...	6	...	...	...	7	...	...	...	8
8 h. 0 m.	...	...	5	...	...	...	6	...	...	...	7	...	...	...	8	...
30 „	...	5	...	...	...	6	...	...	...	7	...	...	...	8	...	...
9 h. 0 m.	5	...	...	...	6	...	...	...	7	...	...	...	8	...	...	...
30 „	...	...	...	6	...	...	...	7	...	...	...	8	...	...	...	9
10 h. 0 m.	...	...	6	...	...	...	7	...	...	...	8	...	...	...	9	...
30 „	...	6	...	...	...	7	...	...	...	8	...	...	...	9	...	...
11 h. 0 m.	6	...	...	...	7	...	...	...	8	...	...	...	9	...	...	...
30 „	...	...	...	7	...	...	...	8	...	...	...	9	...	...	...	10
12 h. 0 m.	...	...	7	...	...	...	8	...	...	...	9	...	...	...	10	...
30 „	...	7	...	...	...	8	...	...	...	9	...	...	...	10	...	...
*13 h. 0 m.	7	...	...	...	8	...	...	...	9	...	...	...	10	...	...	...
30 „	...	...	...	8	...	...	...	9	...	...	...	10	...	...	...	11
14 h. 0 m.	...	...	8	...	...	...	9	...	...	...	10	...	...	...	11	...
30 „	...	8	...	...	...	9	...	...	...	10	...	...	...	11	...	...
15 h. 0 m.	8	...	...	...	9	...	...	...	10	...	...	...	11	...	...	...
30 „	...	...	...	9	...	...	...	10	...	...	...	11	...	...	...	12
16 h. 0 m.	...	...	9	...	...	...	10	...	...	...	11	...	...	...	12	...
30 „	...	9	...	...	...	10	...	...	...	11	...	...	...	12	...	...
17 h. 0 m.	9	...	...	...	10	...	...	...	11	...	...	...	12	...	...	...
30 „	...	...	...	10	...	...	...	11	...	...	...	12	...	...	...	1
18 h. 0 m.	...	...	10	...	...	...	11	...	...	...	12	...	...	...	1	...
30 „	...	10	...	...	...	11	...	...	...	12	...	...	...	1	...	...
19 h. 0 m.	10	...	...	...	11	...	...	...	12	...	...	...	1	...	...	...
30 „	...	...	...	11	...	...	...	12	...	...	...	1	...	...	...	2
20 h. 0 m.	...	...	11	...	...	...	12	...	...	...	1	...	...	...	2	...

TABLE 5, FOR THE NORTHERN HEMISPHERE—*continued.*

TIME.	SEPTEMBER				OCTOBER				NOVEMBER				DECEMBER			
	6	14	21	28	6	14	21	28	6	14	21	28	6	14	21	28
4 h. 0 m.	...	...	7	...	...	...	8	...	...	...	9	...	...	...	10	...
30 „	...	7	...	...	...	8	...	...	...	9	...	...	...	10	...	...
5 h. 0 m.	7	...	...	...	8	...	...	...	9	...	...	...	10	...	...	...
30 „	...	...	...	8	...	...	...	9	...	...	...	10	...	...	...	11
6 h. 0 m.	...	...	8	...	...	...	9	...	...	...	10	...	...	...	11	...
30 „	...	8	...	...	...	9	...	...	...	10	...	...	...	11	...	...
7 h. 0 m.	8	...	...	...	9	...	...	...	10	...	...	...	11	...	...	...
30 „	...	...	...	9	...	...	...	10	...	...	...	11	...	...	...	12
8 h. 0 m.	...	...	9	...	...	...	10	...	...	...	11	...	...	...	12	...
30 „	...	9	...	...	...	10	...	...	...	11	...	...	...	12	...	...
9 h. 0 m.	9	...	...	...	10	...	...	...	11	...	...	...	12	...	...	...
30 „	...	...	...	10	...	...	...	11	...	...	...	12	...	...	...	1
10 h. 0 m.	...	...	10	...	...	...	11	...	...	...	12	...	...	...	1	...
30 „	...	10	...	...	...	11	...	...	...	12	...	...	...	1	...	...
11 h. 0 m.	10	...	...	...	11	...	...	...	12	...	...	...	1	...	...	...
30 „	...	...	...	11	...	...	...	12	...	...	...	1	...	...	...	2
12 h. 0 m.	...	...	11	...	...	...	12	...	...	...	1	...	...	...	2	...
30 „	...	11	...	...	...	12	...	...	...	1	...	...	...	2	...	...
* 13 h. 0 m.	11	...	...	...	12	...	...	...	1	...	...	...	2	...	...	...
30 „	...	...	...	12	...	...	...	1	...	...	...	2	...	...	...	3
14 h. 0 m.	...	...	12	...	...	...	1	...	...	...	2	...	...	...	3	...
30 „	...	12	...	...	...	1	...	...	...	2	...	...	...	3	...	...
15 h. 0 m.	12	...	...	...	1	...	...	...	2	...	...	...	3	...	...	...
30 „	...	...	...	1	...	...	...	2	...	...	...	3	...	...	...	4
16 h. 0 m.	...	...	1	...	...	...	2	...	...	...	3	...	...	...	4	...
30 „	...	1	...	...	...	2	...	...	...	3	...	...	...	4	...	...
17 h. 0 m.	1	...	...	...	2	...	...	...	3	...	...	...	4	...	...	...
30 „	...	...	...	2	...	...	...	3	...	...	...	4	...	...	...	5
18 h. 0 m.	...	...	2	...	...	...	3	...	...	...	4	...	...	...	5	...
30 „	...	2	...	...	...	3	...	...	...	4	...	...	...	5	...	...
19 h. 0 m.	2	...	...	...	3	...	...	...	4	...	...	...	5	...	...	...
30 „	...	...	...	3	...	...	...	4	...	...	...	5	...	...	...	6
20 h. 0 m.	...	...	3	...	...	...	4	...	...	...	5	...	...	...	6	...

TABLE 5*a*. FOR ASCERTAINING THE TIME OF A STAR'S MERIDIAN PASSAGE.

RIGHT ASCENSION *that is on the Meridian.*	*No. of Circular Map.*		RIGHT ASCENSION *that is on the Meridian.*	*No. of Circular Map.*		RIGHT ASCENSION *that is on the Meridian.*	*No. of Circular Map.*		RIGHT ASCENSION *that is on the Meridian.*	*No. of Circular Map.*		RIGHT ASCENSION *that is on the Meridian.*	*No. of Circular Map.*	
	N.	*S.*		*N.*	*S.*		*N.*	*S.*		*N.*	*S.*		*N.*	*S.*
0 h. 0 m.	11	23	5 h. 0 m.	...	...	10 h. 0 m.	4	16	15 h. 0 m.	...	...	20 h. 0 m.	9	21
30 „	...	...	30 „	...	...	30 „	...	...	30 „	...	...	30 „	...	...
1 h. 0 m.	...	...	6 h. 0 m.	2	14	11 h. 0 m.	...	...	16 h. 0 m.	7	19	21 h. 0 m.	...	...
30 „	...	...	30 „	...	...	30 „	...	...	30 „	...	...	30 „	...	...
2 h. 0 m.	12	24	7 h. 0 m.	...	...	12 h. 0 m.	5	17	17 h. 0 m.	...	...	22 h. 0 m.	10	22
30 „	...	...	30 „	...	...	30 „	...	...	30 „	...	...	30 „	...	...
3 h. 0 m.	...	...	8 h. 0 m.	3	15	13 h. 0 m.	...	...	18 h. 0 m.	8	20	23 h. 0 m.	...	...
30 „	...	...	30 „	...	...	30 „	...	...	30 „	...	...	30 „	...	...
4 h. 0 m.	1	13	9 h. 0 m.	...	...	14 h. 0 m.	6	18	19 h. 0 m.	...	...	0 h. 0 m.	11	23
30 „	...	...	30 „	...	...	30 „	...	...	30 „	...	...			

By means of Table 5, the positions of the stars above the horizon may readily be ascertained for any date and hour. The circular map, representing the appearance of the heavens for the required time, is given in the column under the nearest date, and in the same line as the time indicated at the side. If the date cannot be found which will often happen, as four only for each month are given, the one in the table nearest to the date required will indicate with sufficient accuracy the map representing the aspect of the starry sky.

From the manner in which the circular maps are arranged, the approximate time at which any constellation or star culminates may also be ascertained. Knowing the Right Ascension of the object, which can be easily found from the large star charts, the small circular map, having this Right Ascension on the meridian, is given in Table 5*a*. Turning now to Table 5, the corresponding time will be found at the side opposite the number of the map indicated in the column of the given date. Suppose, for example, it is required to ascertain at what time the constellation of Aries crosses the meridian on the 6th of November. From the large charts, the Right Ascension of the group is found to be about two hours. This, in Table 5*a*, gives map 12, while in Table 5, in the column of 6th November, and in a line with 12, will be found the corresponding time when the constellation of the Ram crosses the meridian. From Tables 7 and 8, on page 126, the time of a star's rising or setting may be ascertained.

* *NOTE.*—In Astronomical reckoning, the day is divided into twenty-four hours, numbering from noon of the one day to noon of the next. At midnight, instead of being I., II., III. hours again as in Civil or Ordinary Time, astronomers continue the hours XIII., XIV., XV., and so on. Thus 4 P.M. is 4 hours, 1 A.M. is 13 hours, 5 A.M. is 17 hours, &c.; Noon is called 0 hours 0 minutes, or, contracted, 0 h. 0 m.

TABLE 6.

FOR FINDING THE STARS VISIBLE IN THE SOUTHERN HEMISPHERE,

AT DIFFERENT DATES AND HOURS, BY MEANS OF THE CIRCULAR MAPS.

TIME.	JANUARY				FEBRUARY				MARCH				APRIL			
	5	13	20	27	5	13	20	27	7	15	22	29	6	14	21	28
4 h. 0 m.	...	...	23	...	...	...	24	...	...	...	13	...	...	...	14	...
30 „	...	23	...	...	...	24	...	...	...	13	...	...	...	14	...	...
5 h. 0 m.	23	...	...	...	24	...	...	...	13	...	...	...	14	...	...	...
30 „	...	...	...	24	...	...	...	13	...	...	...	14	...	...	...	15
6 h. 0 m.	...	...	24	...	...	...	13	...	...	...	14	...	...	...	15	...
30 „	...	24	...	...	...	13	...	...	...	14	...	...	...	15	...	...
7 h. 0 m.	24	...	...	...	13	...	...	...	14	...	...	...	15	...	...	...
30 „	...	...	...	13	...	...	...	14	...	...	...	15	...	...	...	16
8 h. 0 m.	...	...	13	...	...	...	14	...	...	...	15	...	...	...	16	...
30 „	...	13	...	...	...	14	...	...	...	15	...	...	...	16	...	...
9 h. 0 m.	13	...	...	...	14	...	...	...	15	...	...	...	16	...	...	...
30 „	...	...	...	14	...	...	...	15	...	...	...	16	...	...	...	17
10 h. 0 m.	...	...	14	...	...	...	15	...	...	...	16	...	...	...	17	...
30 „	...	14	...	...	...	15	...	...	...	16	...	...	...	17	...	...
11 h. 0 m.	14	...	...	...	15	...	...	...	16	...	...	...	17	...	...	...
30 „	...	...	...	15	...	...	...	16	...	...	...	17	...	...	...	18
12 h. 0 m	...	...	15	...	...	...	16	...	...	...	17	...	...	...	18	...
30 „	...	15	...	...	...	16	...	...	...	17	...	...	...	18	...	...
* 13 h. 0 m.	15	...	...	...	16	...	...	...	17	...	...	...	18	...	...	...
30 „	...	...	...	16	...	...	...	17	...	...	...	18	...	...	...	19
14 h. 0 m.	...	...	16	...	...	...	17	...	...	...	18	...	...	...	19	...
30 „	...	16	...	...	...	17	...	...	...	18	...	...	...	19	...	...
15 h. 0 m.	16	...	...	...	17	...	...	...	18	...	...	...	19	...	...	...
30 „	...	...	...	17	...	...	...	18	...	...	...	19	...	...	...	20
16 h. 0 m	...	...	17	...	...	...	18	...	...	...	19	...	...	...	20	...
30 „	...	17	...	...	...	18	...	...	...	19	...	...	...	20	...	...
17 h. 0 m.	17	...	...	...	18	...	...	...	19	...	...	...	20	...	...	...
30 „	...	...	...	18	...	...	...	19	...	...	...	20	...	...	...	21
18 h. 0 m.	...	...	18	...	...	...	19	...	...	...	20	...	...	...	21	...
30 „	...	18	...	...	...	19	...	...	...	20	...	...	...	21	...	...
19 h. 0 m.	18	...	...	...	19	...	...	...	20	...	...	...	21	...	...	...
30 „	...	...	...	19	...	...	...	20	...	...	...	21	...	...	...	22
20 h. 0 m.	...	...	19	...	...	...	20	...	...	...	21	...	...	...	22	...

TIME.	MAY				JUNE				JULY				AUGUST			
	7	15	22	29	6	14	21	28	7	15	22	29	6	14	21	28
4 h. 0 m.	...	...	15	...	...	...	16	...	...	...	17	...	...	...	18	...
30 „	...	15	...	...	...	16	...	...	...	17	...	...	...	18	...	...
5 h. 0 m.	15	...	...	...	16	...	...	...	17	...	...	...	18	...	...	...
30 „	...	...	...	16	...	...	...	17	...	...	...	18	...	...	...	19
6 h. 0 m.	...	...	16	...	...	...	17	...	...	...	18	...	...	...	19	...
30 „	...	16	...	...	...	17	...	...	...	18	...	...	...	19	...	...
7 h. 0 m.	16	...	...	...	17	...	...	...	18	...	...	...	19	...	...	...
30 „	...	...	...	17	...	...	...	18	...	...	...	19	...	...	...	20
8 h. 0 m.	...	...	17	...	...	...	18	...	...	...	19	...	...	...	20	...
30 „	...	17	...	...	...	18	...	...	...	19	...	...	...	20	...	...
9 h. 0 m.	17	...	...	...	18	...	...	...	19	...	...	...	20	...	...	...
30 „	...	...	...	18	...	...	...	19	...	...	...	20	...	...	...	21
10 h. 0 m.	...	...	18	...	...	...	19	...	...	...	20	...	...	...	21	...
30 „	...	18	...	...	...	19	...	...	...	20	...	...	...	21	...	...
11 h. 0 m.	18	...	...	...	19	...	...	...	20	...	...	...	21	...	...	...
30 „	...	...	...	19	...	...	...	20	...	...	...	21	...	...	...	22
12 h. 0 m.	...	...	19	...	...	...	20	...	...	...	21	...	...	...	22	...
30 „	...	19	...	...	...	20	...	...	...	21	...	...	...	22	...	...
* 13 h. 0 m.	19	...	...	...	20	...	...	...	21	...	...	...	22	...	...	...
30 „	...	...	...	20	...	...	...	21	...	...	...	22	...	...	...	23
14 h. 0 m.	...	...	20	...	...	...	21	...	...	...	22	...	...	...	23	...
30 „	...	20	...	...	...	21	...	...	...	22	...	...	...	23	...	...
15 h. 0 m.	20	...	...	...	21	...	...	...	22	...	...	...	23	...	...	...
30 „	...	...	...	21	...	...	...	22	...	...	...	23	...	...	...	24
16 h. 0 m.	...	...	21	...	...	...	22	...	...	...	23	...	...	...	24	...
30 „	...	21	...	...	...	22	...	...	...	23	...	...	...	24	...	...
17 h. 0 m.	21	...	...	...	22	...	...	...	23	...	...	...	24	...	...	...
30 „	...	...	...	22	...	...	...	23	...	...	...	24	...	...	...	13
18 h. 0 m.	...	...	22	...	...	...	23	...	...	...	24	...	...	...	13	...
30 „	...	22	...	...	...	23	...	...	...	24	...	...	...	13	...	...
19 h. 0 m.	22	...	...	...	23	...	...	...	24	...	...	...	13	...	...	...
30 „	...	...	...	23	...	...	...	24	...	...	...	13	...	...	...	14
20 h. 0 m.	...	...	23	...	...	...	24	...	...	...	13	...	...	...	14	...

TABLE 6, FOR THE SOUTHERN HEMISPHERE—*continued.*

TIME.	SEPTEMBER				OCTOBER				NOVEMBER				DECEMBER			
	6	14	21	28	6	14	21	28	6	14	21	28	6	14	21	28
4 h. 0 m.	...	...	19	...	...	...	20	...	...	...	21	...	...	...	22	...
30 „	...	19	...	...	...	20	...	...	...	21	...	...	...	22	...	...
5 h. 0 m.	19	...	...	...	20	...	...	...	21	...	...	...	22	...	...	...
30 „	...	...	...	20	...	...	...	21	...	...	...	22	...	...	...	23
6 h. 0 m.	...	...	20	...	...	...	21	...	...	...	22	...	...	...	23	...
30 „	...	20	...	...	...	21	...	...	...	22	...	...	...	23	...	...
7 h. 0 m.	20	...	...	...	21	...	...	...	22	...	...	...	23	...	...	...
30 „	...	...	...	21	...	...	...	22	...	...	...	23	...	...	...	24
8 h. 0 m.	...	...	21	...	...	...	22	...	...	...	23	...	...	...	24	...
30 „	...	21	...	...	...	22	...	...	...	23	...	...	...	24	...	...
9 h. 0 m.	21	...	...	...	22	...	...	...	23	...	...	...	24	...	...	...
30 „	...	...	...	22	...	...	...	23	...	...	...	24	...	...	...	13
10 h. 0 m.	...	...	22	...	...	...	23	...	...	...	24	...	...	...	13	...
30 „	...	22	...	...	...	23	...	...	...	24	...	...	...	13	...	...
11 h. 0 m.	22	...	...	...	23	...	...	...	24	...	...	...	13	...	...	...
30 „	...	...	...	23	...	...	...	24	...	...	...	13	...	...	...	14
12 h. 0 m.	...	...	23	...	...	...	24	...	...	...	13	...	...	...	14	...
30 „	...	23	...	...	...	24	...	...	...	13	...	...	...	14	...	...
*13 h. 0 m.	23	...	...	...	24	...	...	...	13	...	...	...	14	...	...	...
30 „	...	...	...	24	...	...	...	13	...	...	...	14	...	...	...	15
14 h. 0 m.	...	...	24	...	...	...	13	...	...	...	14	...	...	...	15	...
30 „	...	24	...	...	...	13	...	...	...	14	...	...	...	15	...	...
15 h. 0 m.	24	...	...	...	13	...	...	...	14	...	...	...	15	...	...	...
30 „	...	...	...	13	...	...	...	14	...	...	...	15	...	...	...	16
16 h. 0 m.	...	...	13	...	...	...	14	...	...	...	15	...	...	...	16	...
30 „	...	13	...	...	...	14	...	...	...	15	...	...	...	16	...	...
17 h. 0 m.	13	...	...	...	14	...	...	...	15	...	...	...	16	...	...	...
30 „	...	...	...	14	...	...	...	15	...	...	...	16	...	...	...	17
18 h. 0 m.	...	...	14	...	...	...	15	...	...	...	16	...	...	...	17	...
30 „	...	14	...	...	...	15	...	...	...	16	...	...	...	17	...	...
19 h. 0 m.	14	...	...	...	15	...	...	...	16	...	...	...	17	...	...	...
30 „	...	...	...	15	...	...	...	16	...	...	...	17	...	...	...	18
20 h. 0 m.	...	...	15	...	...	...	16	...	...	...	17	...	...	...	18	...

TABLE 6*a*. FOR ASCERTAINING THE TIME OF A STAR'S MERIDIAN PASSAGE.

RIGHT ASCENSION *that is on the Meridian.*	*No. of Circular Map.*		RIGHT ASCENSION *that is on the Meridian.*	*No. of Circular Map.*		RIGHT ASCENSION *that is on the Meridian.*	*No. of Circular Map.*		RIGHT ASCENSION *that is on the Meridian.*	*No. of Circular Map.*		RIGHT ASCENSION *that is on the Meridian.*	*No. of Circular Map.*	
	S.	*N.*		*S.*	*N.*		*S.*	*N.*		*S.*	*N.*		*S.*	*N.*
0 h. 0 m.	23	11	5 h. 0 m.	...	...	10 h. 0 m.	16	4	15 h. 0 m.	...	...	20 h. 0 m.	21	9
30 „	...	...	30 „	...	...	30 „	...	...	30 „	...	...	30 „	...	...
1 h. 0 m.	...	...	6 h. 0 m.	14	2	11 h. 0 m.	...	...	16 h. 0 m.	19	7	21 h. 0 m.	...	...
30 „	...	...	30 „	...	...	30 „	...	...	30 „	...	...	30 „	...	...
2 h. 0 m.	24	12	7 h. 0 m.	...	...	12 h. 0 m.	17	5	17 h. 0 m.	...	...	22 h. 0 m.	22	10
30 „	...	...	30 „	...	...	30 „	...	...	30 „	...	...	30 „	...	...
3 h. 0 m.	...	...	8 h. 0 m.	15	3	13 h. 0 m.	...	...	18 h. 0 m.	20	8	23 h. 0 m.	...	...
30 „	...	...	30 „	...	...	30 „	...	...	30 „	...	...	30 „	...	...
4 h. 0 m.	13	1	9 h. 0 m.	...	...	14 h. 0 m.	18	6	19 h. 0 m.	...	...	0 h. 0 m.	23	11
30 „	...	...	30 „	...	...	30 „	...	...	30 „	...	...			

By means of Table 6, the positions of the stars above the horizon may readily be ascertained for any date and hour. The circular map, representing the appearance of the heavens for the required time, is given in the column under the nearest date, and in the same line as the time indicated at the side. If the date cannot be found which will often happen, as four only for each month are given, the one in the table nearest to the date required will indicate with sufficient accuracy the map representing the aspect of the starry sky.

From the manner in which the circular maps are arranged, the approximate time at which any constellation or star culminates may also be ascertained. Knowing the Right Ascension of the object, which can be easily found from the large star charts, the small circular map, having this Right Ascension on the meridian, is given in Table 6*a*. Turning now to Table 6, the corresponding time will be found at the side opposite the number of the map indicated in the column of the given date. Suppose, for example, it is required to ascertain at what time the constellation of Aries crosses the meridian on the 6th of November. From the large charts, the Right Ascension of the group is found to be about two hours. This, in Table 6*a*, gives map 24, while in Table 6, in the column of 6th November, and in a line with 24, will be found the corresponding time when the constellation of the Ram crosses the meridian. From Tables 7 and 8, on page 126, the time of a star's rising or setting may be ascertained.

* *NOTE.*—In Astronomical reckoning, the day is divided into twenty-four hours, numbering from noon of the one day to noon of the next. At midnight, instead of being I., II., III. hours again as in Civil or Ordinary Time, astronomers continue the hours XIII., XIV., XV., and so on. Thus 4 P.M. is 4 hours, 1 A.M. is 13 hours, 5 A.M. is 17 hours, &c. ; Noon is called 0 hours 0 minutes, or, contracted, 0 h. 0 m.

TABLE 7.—SIDEREAL TIME,

Or Hour and Minute of Right Ascension on the Meridian at Noon on the following dates:—

DAY OF THE MONTH.	JANUARY.	FEB.	MARCH.	APRIL.	MAY.	JUNE.	JULY.	AUGUST.	SEPT.	OCT.	NOV.	DEC.
	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.
5	19 0	21 2	22 53	0 55	2 53	4 55	6 54	8 56	10 58	12 56	14 59	16 57
10	19 20	21 22	23 12	1 15	3 13	5 15	7 13	9 16	11 18	13 16	15 18	17 17
15	19 40	21 42	23 32	1 35	3 33	5 35	7 33	9 35	11 38	13 36	15 38	17 36
20	20 0	22 1	23 52	1 54	3 52	5 55	7 53	9 55	11 57	13 56	15 58	17 56
25	20 19	22 21	0 12	2 14	4 12	6 14	8 13	10 15	12 17	14 15	16 18	18 16
30	20 39	...	0 31	2 34	4 32	6 34	8 32	10 35	12 37	14 35	16 37	18 36

For Intermediate Dates add four minutes for each day.

TABLE 8.—TIME BETWEEN A STAR'S RISING OR SETTING AND ITS CULMINATION.

DECLINATION OF STAR.		STAR RISES OR SETS AFTER CULMINATION AT LATITUDE.											
		5°	10°	15°	20°	25°	30°	35°	40°	45°	50°	55°	60°
		h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.
Declination of the SAME *name as the Latitude of the place*—i.e., *if Lat. N. and Dec. N., or if Lat. S. and Dec. S.*	30°	6 11	6 23	6 36	6 49	7 2	7 19	7 35	7 55	8 18	8 53	9 39	11 22
	25°	6 8	6 19	6 29	6 39	6 49	7 2	7 16	7 32	7 51	8 15	8 47	9 35
	20°	6 7	6 15	6 22	6 30	6 39	6 49	6 59	7 11	7 25	7 43	8 5	8 36
	15°	6 5	6 11	6 16	6 22	6 29	6 36	6 43	6 52	7 2	7 14	7 30	7 51
	10°	6 4	6 7	6 11	6 15	6 19	6 23	6 28	6 34	6 41	6 49	6 58	7 11
	5°	6 2	6 4	6 5	6 7	6 9	6 12	6 14	6 17	6 20	6 24	6 29	6 35
Declination of CONTRARY *name to the Latitude of the place*—i.e., *if Lat. N. and Dec. S., or if Lat. S. and Dec. N.*	0°	6 0	6 0	6 0	6 0	6 0	6 0	6 0	6 0	6 0	6 0	6 0	6 0
	5°	5 58	5 56	5 55	5 53	5 51	5 48	5 46	5 43	5 40	5 36	5 31	5 25
	10°	5 56	5 53	5 49	5 45	5 41	5 37	5 32	5 26	5 19	5 11	5 2	4 49
	15°	5 55	5 49	5 44	5 38	5 31	5 24	5 17	5 8	4 58	4 46	4 30	4 9
	20°	5 53	5 45	5 38	5 30	5 21	5 11	5 1	4 49	4 35	4 17	3 55	3 24
	25°	5 52	5 41	5 31	5 21	5 11	4 58	4 44	4 28	4 9	3 45	3 13	2 25
	30°	5 49	5 37	5 24	5 11	4 58	4 41	4 25	4 5	3 42	3 7	2 21	0 38

By means of the above Tables the approximate time of the rising and setting of a star may easily be found. The time of culminating, as already mentioned, can be roughly ascertained by aid of Tables 5*a* and 6*a*. This information, however, can be found with far greater accuracy from Table 7, which gives the sidereal time for different days throughout the year, or the hour and minute of Right Ascension that is on the meridian at noon. From this, the time of a star's meridian passage may be found very nearly, by simply subtracting the sidereal time for the date required from the star's Right Ascension. If, now, the number of hours and minutes found in Table 8 for the latitude of the place and the Declination of the star be added to, or subtracted from, the time of crossing the meridian, the approximate time of rising and setting will be ascertained.

Suppose, for example, the time is required at which the bright star *Procyon* rises, culminates, and sets on the 10th of January in latitude 50 degrees North. From the Table of the Positions of the Stars, on pages 127 to 135, the Right Ascension of the star is found to be 7 h. 33 m., and the Declination 5° 30′ N.; while in Table 7 the sidereal time for the given date is 19 h. 20 m. This has now to be subtracted from the Right Ascension of the star (to which 24 h. has to be added, as in this case the Right Ascension is less than the sidereal time), in order to ascertain the approximate time of meridian passage, which is 12 h. 13 m. Lastly, from Table 8, for latitude 50° N., and Declination 5° N., the time at which the star rises before and sets after culmination, is found to be 6 h. 24 m.; and this subtracted from 12 h. 13 m., the time of meridian passage, gives 5 h. 49 m. and 18 h. 37 m. for the rising and setting respectively.

TABLE 9.—THE NAMES AND POSITIONS OF THE MORE IMPORTANT STARS,

REDUCED TO EPOCH OF 1890.

No.	*CONSTELLATION.*	*Greek or Roman Letter, and Synonym.*	*Flamsteed Number.*	*B.A.C.*	*MAGNITUDE.*	*RIGHT ASCENSION.*			*DECLINATION.*
						h.	m.	s.	
1	ANDROMEDA,	α (*Alpheratz*),	21	4	2·1	0	2	42	28° 28′ 59″ N.
2	CASSIOPEIA,	β (*Chaph*),	11	7	2·4	0	3	18	58° 32′ 37″ N.
3	PHŒNIX,	ε,	...	11	3·9	0	3	49	46° 21′ 14″ S.
4	PEGASUS,	γ (*Algenib*),	88	26	3·0	0	7	34	14° 34′ 19″ N.
5	CETUS,	ι (*Dheneb Kaitos*),	8	62	3·6	0	13	49	9° 26′ 2″ S.
6	HYDRUS,	β,	...	88	2·8	0	19	57	77° 52′ 26″ S.
7	PHŒNIX,	ϰ,	...	93	4·0	0	20	47	44° 17′ 24″ S.
8	PHŒNIX,	α,	...	94	2·4	0	20	1	42° 54′ 10″ S.
9	CASSIOPEIA,	ϰ,	15	126	4·2	0	26	45	62° 19′ 30″ N.
10	CASSIOPEIA,	ζ,	17	153	3·7	0	30	51	53° 17′ 31″ N.
11	ANDROMEDA,	π,	29	155	4·3	0	31	0	33° 6′ 51″ N.
12	ANDROMEDA,	ε,	30	164	4·6	0	32	45	28° 42′ 57″ N.
13	ANDROMEDA,	δ,	31	166	3·4	0	33	27	30° 15′ 30″ N.
14	CASSIOPEIA,	α (*Schedir*),	18	169	2·2	0	34	16	55° 56′ 2″ N.
15	CETUS,	β (*Diphda*),	16	196	2·1	0	38	4	18° 35′ 25″ S.
16	CASSIOPEIA,	η,	24	218	3·6	0	42	27	57° 13′ 56″ N.
17	CASSIOPEIA,	γ,	27	253	2·3	0	50	4	60° 7′ 17″ N.
18	ANDROMEDA,	μ,	37	259	3·9	0	50	39	37° 54′ 12″ N.
19	PISCES,	ε,	71	288	4·5	0	57	14	7° 17′ 51″ N.
20	PHŒNIX,	β,	...	317	3·4	1	1	10	47° 18′ 28″ S.
21	CETUS,	η (*Dheneb*),	31	332	3·6	1	3	3	10° 45′ 54″ S.
22	ANDROMEDA,	β (*Mirach*),	43	334	2·2	1	3	34	35° 2′ 14″ N.
23	URSA MINOR,	α (*Polaris*),	1	360	2·2	1	18	29	88° 43′ 18″ N.
24	CASSIOPEIA,	δ,	37	416	2·9	1	18	37	59° 39′ 48″ N.
25	CETUS,	θ,	45	420	3·8	1	18	31	8° 45′ 4″ S.
26	PHŒNIX,	γ,	...	447	3·5	1	23	35	43° 52′ 43″ S
27	PISCES,	η,	99	453	3·8	1	25	36	14° 46′ 42″ N.
28	ANDROMEDA,	ν,	51	487	3·7	1	31	15	48° 4′ 14″ N.
29	ERIDANUS,	α (*Achernar*),	...	507	0·5	1	33	37	57° 47′ 45″ S.
30	ANDROMEDA,	φ,	54	522	4·2	1	36	46	50° 8′ 2″ N.
31	CETUS,	τ,	52	536	3·6	1	38	58	16° 30′ 59″ S.
32	CASSIOPEIA,	ε,	45	564	3·6	1	46	29	63° 7′ 42″ N.
33	CETUS,	ζ (*Baten-kaitos*),	55	565	3·9	1	46	2	10° 52′ 49″ S.
34	TRIANGULA,	α,	2	569	3·6	1	46	49	29° 2′ 37″ N.
35	ARIES,	γ (*Mesarthim*),	5	572	4·3	1	47	30	18° 45′ 16″ N.
36	ARIES,		5	573					
37	ARIES,	β (*Sheratan*),	6	577	2·8	1	48	34	20° 16′ 12″ N.
38	ERIDANUS,	χ,	...	596	4·0	1	51	40	52° 11′ 27″ S.
39	CASSIOPEIA,	......	50	600	4·0	1	54	3	71° 53′ 19″ N.
40	CETUS,	υ,	59	618	3·8	1	54	49	21° 36′ 39″ S.
41	HYDRUS,	α,	...	623	3·0	1	55	18	62° 6′ 11″ S.
42	PISCES,	α (*Kaïtaïn*),	113	625	4·0	1	56	22	2° 13′ 58″ N.
43	ANDROMEDA,	γ (*Almach*),	57	628	2·2	1	57	9	41° 48′ 7″ N.
44	ARIES,	α (*Hamal*),	13	648	2·1	2	0	58	22° 56′ 31″ N.
45	TRIANGULUM,	β,	4	656	3·1	2	3	0	34° 28′ 2″ N.
46	ERIDANUS,	φ,	...	717	3·6	2	12	34	52° 1′ 16″ S.
47	CETUS,	ο (*Mira*),	68	720	Var. 2 to 7	2	13	47	3° 28′ 40″ S.
48	HYDRUS,	δ,	...	756	4·2	2	19	48	69° 9′ 56″ S.
49	CETUS,	ξ^2,	73	760	4·5	2	22	19	7° 58′ 0″ N.
50	CETUS,	δ,	82	811	4·1	2	33	51	0° 8′ 50″ S.

THE NAMES AND POSITIONS OF THE MORE IMPORTANT STARS, &c.—*continued.*

No.	*CONSTELLATION.*	*Greek or Roman Letter, and Synonym.*	*Flamsteed Number.*	*B A.C.*	*MAGNITUDE.*	*RIGHT ASCENSION.*	*DECLINATION.*
						h. m. s.	
51	PERSEUS, . . .	θ, ...	13	827	4·3	2 36 41	48° 45′ 46″ N.
52	CETUS, . . .	γ (*Kaff-al-jidhina*),	86	837	3·6	2 37 36	2° 46′ 17″ N.
53	CETUS, . . .	τ, ...	89	847	4·3	2 38 53	14° 19′ 31″ S.
54	PERSEUS, . . .	η, ...	15	863	4·0	2 42 40	55° 26′ 19″ N.
55	ARIES, . . .	......	41	872	3·8	2 43 30	26° 48′ 27″ N.
56	PERSEUS, . . .	τ, ...	18	885	4·0	2 46 28	52° 18′ 43″ N.
57	ERIDANUS, . .	η, ...	3	910	4·0	2 51 3	9° 20′ 11″ S.
58	ERIDANUS, . .	θ, ...	...	937	2·7	2 54 5	40° 44′ 34″ S.
59	PERSEUS, . . .	γ, ...	23	947	3·1	2 56 50	53° 4′ 31″ N.
60	CETUS, . . .	α, ...	92	949	2·7	2 56 32	3° 39′ 27″ N.
61	PERSEUS, . . .	ϱ, ...	25	953	3·7	2 58 8	38° 24′ 51″ N.
62	ERIDANUS, . .	τ^3, ...	11	954	4·1	2 57 33	24° 3′ 22″ S.
63	PERSEUS, . . .	ι, ...	...	962	4·1	3 1 7	49° 11′ 38″ N.
64	PERSEUS, . . .	β (*Algol*), . .	26	963	2·3	3 1 2	40° 31′ 54″ N.
65	ARIES, . . .	δ, ...	57	986	4·5	3 5 20	19° 18′ 37″ N.
66	ERIDANUS, . .	......	12	997	3·8	3 7 23	29° 25′ 23″ S.
67	ERIDANUS, . .	τ^4, ...	16	1037	3·8	3 14 37	22° 9′ 32″ S.
68	PERSEUS, . . .	α (*Mirfak*), . .	33	1043	2·0	3 16 28	49° 28′ 8″ N.
69	TAURUS, . . .	ο, ...	1	1057	3·8	3 18 54	8° 38′ 24″ N.
70	TAURUS, . . .	ξ, ...	2	1068	3·8	3 21 13	9° 20′ 56″ N.
71	ERIDANUS, . .	ε, ...	18	1100	3·7	3 27 45	9° 49′ 52″ S.
72	PERSEUS, . . .	δ, ...	39	1129	3·2	3 35 6	47° 26′ 7″ N.
73	PERSEUS, . . .	ο, ...	38	1138	4·0	3 37 25	31° 56′ 25″ N.
74	PERSEUS, . .	ν, ...	41	1139	4·0	3 37 43	42° 13′ 51″ N.
75	TAURUS, . . .	......	17	1147	3·8	3 38 21	23° 46′ 2″ N.
76	ERIDANUS, . .	δ, ...	23	1148	3·7	3 37 59	10° 8′ 12″ S.
77	TAURUS, . . .	η, ...	25	1166	3·0	3 40 57	23° 45′ 52″ N.
78	TAURUS, . . .	......	27	1176	3·8	3 42 37	23° 43′ 1″ N.
79	PERSEUS, . . .	ζ, ...	44	1207	3·1	3 47 13	31° 33′ 24″ N.
80	PERSEUS, . . .	ε, ...	45	1219	3·1	3 50 28	39° 41′ 29″ N.
81	HYDRUS, . . .	γ, ...	...	1230	3·3	3 48 57	74° 34′ 32″ S.
82	ERIDANUS, . .	γ (*Zaurak*), . .	34	1234	3·0	3 52 54	13° 49′ 20″ S.
83	TAURUS, . . .	λ, ...	35	1241	3·6	3 54 35	12° 10′ 47″ N.
84	ERIDANUS, . .	o^1 (*Beïd*), . .	38	1290	4·1	4 6 30	7° 7′ 29″ S.
85	TAURUS, . . .	γ (*HyadumPrimus*),	54	1328	3·9	4 13 32	15° 21′ 41″ N.
86	ERIDANUS, . .	υ^4, ...	41	1333	3·3	4 13 43	34° 4′ 2″ S.
87	RETICULUM, . .	α, ...	...	1336	3·4	4 12 59	62° 44′ 58″ S.
88	TAURUS, . . .	δ, ...	61	1346	4·0	4 16 35	17° 17′ 3″ N.
89	ERIDANUS, . .	υ^3, ...	43	1372	4·0	4 19 53	34° 16′ 22″
90	TAURUS, . . .	ε, ...	74	1376	3·7	4 22 12	18° 56′ 9″ N.
91	TAURUS, . . .	θ^1 (*Alya*), . .	77	1380	3·9	4 22 17	15° 43′ 4″ N.
92	TAURUS, . . .	θ^2	78	1381	3·6	4 21 15	15° 34′ 49″ N.
93	TAURUS, . . .	α (*Aldebaran*), .	87	1420	1·0	4 29 36	16° 17′ 15″ N.
94	ERIDANUS, . .	ν, ...	48	1429	3·9	4 30 50	3° 34′ 39″ S.
95	ERIDANUS, . .	υ^2, ...	52	1433	3·8	4 31 16	30° 47′ 15″ S.
96	DORADO, . . .	α, ...	...	1438	3·2	4 31 37	55° 16′ 20″ S.
97	ERIDANUS, . .	......	53	1441	3·9	4 33 9	14° 31′ 10″ S.
98	ERIDANUS, . .	μ, ...	57	1469	4·3	4 40 0	3° 27′ 25″ S.
99	ORION, . . .	τ^3, ...	1	1486	3·3	4 43 53	6° 46′ 4″ N.
100	ORION, . . .	τ^4, ...	3	1495	4·0	4 45 21	5° 24′ 56″ N.
101	ORION, . . .	τ^5, ...	8	1514	3·9	4 48 31	2° 15′ 37″ N.
102	AURIGA, . . .	ι, ...	3	1520	2·7	4 49 50	32° 59′ 28″ N.

THE NAMES AND POSITIONS OF THE MORE IMPORTANT STARS, &c.—*continued.*

No.	CONSTELLATION.	*Greek or Roman Letter, and Synonym.*	*Flamsteed Number.*	*B.A.C.*	*MAGNITUDE.*	*RIGHT ASCENSION.*	*DECLINATION.*
						h. m. s.	
103	Auriga,	ε,	7	1540	3·2	4 54 5	43° 39′ 36″ N.
104	Auriga,	ζ (*Sadatoni*),	8	1541	4·0	4 54 48	40° 54′ 54″ N.
105	Auriga,	η,	10	1558	3·3	4 58 48	41° 5′ 9″ N.
106	Lepus,	ε,	2	1575	3·3	5 0 48	22° 31′ 9″ S.
107	Eridanus,	β (*Cursa*),	67	1588	2·9	5 2 27	5° 13′ 45″ S.
108	Auriga,	α (*Capella*),	13	1613	0·2	5 8 34	45° 53′ 6″ N.
109	Lepus,	μ,	5	1616	3·3	5 7 59	16° 20′ 8″ S.
110	Orion,	β (*Rigel*),	19	1623	0·3	5 9 15	8° 19′ 46″ S.
111	Orion,	τ,	20	1638	3·7	5 12 16	6° 57′ 51″ S.
112	Taurus,	β (*Nath*),	112	1681	1·9	5 19 20	28° 30′ 49″ N.
113	Orion,	η,	28	1684	3·5	5 18 57	2° 29′ 57″ S.
114	Orion,	γ (*Bellatrix*),	24	1687	1·9	5 19 14	6° 14′ 59″ N.
115	Lepus,	β,	9	1715	3·0	5 23 32	20° 50′ 51″ S.
116	Orion,	δ (*Mintaka*),	34	1730	2·4	5 26 23	0° 22′ 53″ S.
117	Columba,	ε,	...	1739	3·8	5 27 18	35° 33′ 4″ S.
118	Lepus,	α,	11	1741	2·7	5 27 53	17° 54′ 7″ S.
119	Orion,	λ (*Heka*),	39	1749	3·5	5 29 5	9° 51′ 32″ N.
120	Orion,	ι,	44	1762	3·0	5 30 3	5° 58′ 58″ S.
121	Orion,	ε (*Alnilam*),	46	1765	1·8	5 30 38	1° 16′ 22″ S.
122	Taurus,	ζ,	123	1767	3·0	5 31 4	21° 4′ 31″ N.
123	Orion,	σ,	48	1780	3·7	5 33 13	2° 39′ 52″ S.
124	Dorado,	β,	...	1791	4·0	5 32 40	62° 33′ 42″ S.
125	Orion,	ζ (*Alnitak*),	50	1794	1·9	5 35 13	2° 0′ 6″ S.
126	Columba,	α (*Hadar*),	...	1802	2·7	5 35 40	34° 8′ 0″ S.
127	Lepus,	γ,	13	1823	3·8	5 39 53	22° 29′ 1″ S.
128	Lepus,	ζ,	14	1840	3·7	5 41 59	14° 51′ 50″ S.
129	Orion,	κ,	53	1843	2·2	5 42 32	9° 42′ 34″ S.
130	Lepus,	δ,	15	1871	4·0	5 46 35	20° 53′ 14″ S.
131	Columba,	β (*Wezn*),	...	1878	2·9	5 47 4	35° 48′ 41″ S.
132	Orion,	α (*Betelgeux*),	58	1883	0·9	5 49 13	7° 23′ 9″ N.
133	Auriga,	δ,	33	1885	3·8	5 50 28	54° 16′ 33″ N.
134	Auriga,	β (*Menkalinan*),	34	1895	2·1	5 51 27	44° 56′ 5″ N.
135	Auriga,	θ,	37	1900	2·7	5 52 13	37° 12′ 15″ N.
136	Lepus,	η,	16	1901	3·7	5 51 24	14° 11′ 17″ S.
137	Gemini,	η,	7	2002	3·5	6 8 14	22° 32′ 17″ N.
138	Gemini,	μ (*Tejat*),	13	2047	3·2	6 16 18	22° 34′ 9″ N.
139	Canis Major,	ζ (*Phurud*),	1	2051	3·0	6 16 5	30° 0′ 54″ S.
140	Canis Major,	β (*Mirzam*),	2	2061	2·0	6 17 51	17° 54′ 7″ S.
141	Canis Major,	δ,	3	2066	4·0	6 18 4	33° 22′ 51″ S.
142	Gemini,	ν,	18	2090	4·0	6 22 26	20° 16′ 50″ N.
143	Argo,	α (*Canopus*),	...	2096	0·4	6 21 31	52° 38′ 9″ S.
144	Gemini,	γ (*Alhena*),	24	2163	2·0	6 31 21	16° 29′ 33″ N.
145	Argo,	ν,	...	2188	3·6	6 34 24	43° 5′ 58″ S.
146	Gemini,	ε (*Mebsuta*),	27	2194	3·2	6 37 10	25° 14′ 21″ N.
147	Gemini,	ξ,	31	2206	3·4	6 39 7	13° 0′ 48″ N.
148	Canis Major,	α (*Sirius*),	9	2213	*−1·4*	6 40 18	16° 33′ 58″ S.
149	Gemini,	θ,	34	2237	3·7	6 45 32	34° 5′ 35″ N.
150	Canis Major,	κ,	13	2246	3·9	6 45 43	33° 22′ 54″ S.
151	Argo,	τ,	...	2256	3·3	6 47 12	50° 29′ 1″ S.
152	Pictor,	α,	...	2260	3·6	6 46 58	61° 49′ 26″ S.
153	Canis Major,	o^1,	16	2267	4·0	6 49 35	24° 2′ 49″ S.
154	Canis Major,	ε (*Adhara*),	21	2293	1·5	6 54 18	28° 49′ 22″ S.

THE NAMES AND POSITIONS OF THE MORE IMPORTANT STARS, &c.—*continued.*

No.	CONSTELLATION.	Greek or Roman Letter, and Synonym.	Flamsteed Number.	B.A.C.	MAGNITUDE.	RIGHT ASCENSION. h. m. s.	DECLINATION.
155	Gemini,	ζ,	43	2305	4·0	6 57 35	20° 43′ 51″ N.
156	Canis Major,	σ,	22	2309	3·5	6 57 20	27° 46′ 38″ S.
157	Canis Major,	o^2,	24	2318	3·0	6 58 26	23° 40′ 23″ S.
158	Canis Major,	γ,	23	2319	4·1	6 58 47	15° 28′ 17″ S.
159	Canis Major,	δ (*Wezen*),	25	2345	1·8	7 3 55	26° 13′ 8″ S.
160	Canis Major,	......	28	2391	3·7	7 10 21	26° 34′ 55″ S.
161	Gemini,	λ,	54	2398	3·6	7 11 47	16° 44′ 24″ N.
162	Gemini,	δ (*Wasat*),	55	2410	3·7	7 13 33	22° 11′ 3″ N.
163	Argo,	π,	...	2414	2·7	7 13 15	36° 54′ 1″ S.
164	Gemini,	ι,	60	2442	4·0	7 18 54	28° 0′ 58″ N.
165	Canis Major,	η (*Aludra*),	31	2458	2·4	7 19 44	29° 5′ 20″ S.
166	Canis Minor,	β (*Gomeisa*),	3	2462	3·1	7 21 11	8° 30′ 37″ N.
167	Argo,	σ,	...	2482	3·6	7 25 44	43° 4′ 46″ S.
168	Gemini,	α (*Castor*),	66	2485	1·6	7 27 35	32° 7′ 45″ N.
169	Canis Minor,	α (*Procyon*),	10	2522	0·5	7 33 33	5° 30′ 22″ N.
170	Argo,	ϰ,	...	2530 2531	3·9	7 34 19	26° 32′ 7″ S.
171	Gemini,	ϰ,	77	2551	3·6	7 37 48	24° 39′ 41″ N.
172	Gemini,	β (*Pollux*),	78	2555	1·1	7 38 35	28° 17′ 28″ N.
173	Argo,	ξ,	...	2602	3·4	7 44 40	24° 34′ 59″ S.
174	Argo,	χ,	...	2665	3·8	7 54 0	52° 41′ 15″ S.
175	Argo,	ζ,	...	2710	2·6	7 59 43	39° 41′ 36″ S.
176	Argo,	ι,	15	2728	2·9	8 2 52	23° 59′ 15″ S.
177	Argo,	γ,	...	2755	3·0	8 6 9	47° 0′ 46″ S.
178	Cancer,	β,	17	2778	3·8	8 10 33	9° 31′ 26″ N.
179	Ursa Major,	ο,	1	2819	3·4	8 21 8	61° 5′ 8″ N.
180	Monoceros,	......	30	2825	3·9	8 20 10	3° 32′ 46″ S.
181	Argo,	ε,	...	2832	2·1	8 20 16	59° 9′ 20″ S.
182	Argo,	o^2,	...	2964	3·6	8 39 10	32° 47′ 25″ S.
183	Hydra,	ε,	11	2971	3·6	8 40 57	6° 49′ 19″ N.
184	Argo,	δ,	...	2979	2·2	8 41 40	54° 18′ 20″ S.
185	Hydra,	ζ,	16	3032	3·3	8 49 35	6° 21′ 51″ N.
186	Ursa Major,	ι (*Talitha*),	9	3048	3·2	8 51 40	48° 28′ 22″ N.
187	Cancer,	α (*Al Hamarein*),	65	3055	4·3	8 52 28	12° 16′ 59″ N.
188	Ursa Major,	ϰ,	12	3075	3·7	8 56 7	47° 35′ 25″ N.
189	Argo,	λ,	...	3126	2·5	9 3 57	42° 59′ 8″ S.
190	Lynx,	......	38	3162	3·8	9 12 0	37° 16′ 10″ N.
191	Argo,	β,	...	3177	2·0	9 11 59	69° 15′ 51″ S.
192	Lynx,	α,	40	3178	3·4	9 14 21	34° 51′ 23″ N.
193	Argo,	ι,	...	3186	2·5	9 14 9	58° 48′ 49″ S.
194	Argo,	ϰ,	...	3213	2·8	9 18 42	54° 32′ 27″ S.
195	Ursa Major,	h,	23	3221	3·7	9 22 51	63° 32′ 33″ N.
196	Hydra,	α (*Alphard*),	30	3223	2·0	9 22 11	8° 10′ 56″ S.
197	Ursa Major,	θ,	25	3242	3·2	9 25 30	52° 10′ 41″ N.
198	Argo,	ψ,	...	3257	3·8	9 26 22	39° 59′ 8″ S.
199	Leo,	ο,	14	3312	3·8	9 35 17	10° 23 33″ N.
200	Leo,	ε,	17	3331	3·1	9 39 36	24° 16′ 49″ N.
201	Ursa Major,	υ,	29	3346	4·0	9 43 10	59° 33′ 18″ N.
202	Argo,	υ,	...	3365	3·4	9 44 21	64° 33′ 33″ S.
203	Leo,	μ (*Rasalas*),	24	3371	4·1	9 46 30	26° 31′ 28″ N.
204	Leo,	η,	30	3453	3·6	10 1 20	27° 17′ 58″ N.
205	Leo,	α (*Regulus*),	32	3459	1·4	10 2 31	12° 30′ 16″ N.

THE NAMES AND POSITIONS OF THE MORE IMPORTANT STARS, &c.—*continued.*

No.	*CONSTELLATION.*	*Greek or Roman Letter, and Synonym.*	*Flamsteed Number.*	*B.A.C.*	*MAGNITUDE.*	*RIGHT ASCENSION.*	*DECLINATION.*
						h. m. s.	
206	Hydra,	λ,	41	3473	3·9	10 5 14	11° 48′ 37″ s.
207	Ursa Major,	λ,	33	3505	3·6	10 10 28	43° 27′ 48″ n.
208	Leo,	ζ,	...	3508	3·6	10 10 34	23° 57′ 56″ n.
209	Argo,	ω,	...	3516	3·7	10 11 7	69° 29′ 30″ s.
210	Leo,	λ (*Abgeiba*),	41	3523	2·2	10 13 54	20° 23′ 51″ n.
211	Ursa Major,	μ,	34	3533	3·1	10 15 47	42° 3′ 10″ n.
212	Hydra,	μ,	42	3568	4·1	10 20 46	16° 16′ 30″ s.
213	Leo,	ϱ,	47	3609	4·0	10 27 1	9° 52′ 20″ n.
214	Carina,	P,	...	3619	3·7	10 28 6	61° 7′ 11″ s.
215	Argo,	θ,	...	3686	3·0	10 39 2	63° 59′ 7″ s.
216	Argo,	η,	...	3695	Var. 1 to 6	10 40 48	59° 6′ 23″ s.
217	Argo,	μ,	...	3702	3·0	10 42 2	48° 50′ 20″ s.
218	Hydra,	ν,	...	3715	3·3	10 44 12	15° 37′ 8″ s.
219	Leo Minor,	.....	46	3728	3·9	10 47 9	34° 48′ 29″ n.
220	Crater,	α (*Alkes*),	7	3766	4·1	10 54 25	17° 42′ 45″ s.
221	Ursa Major,	β (*Mirak*),	48	3767	2·6	10 55 12	56° 58′ 19″ n.
222	Ursa Major,	α (*Dubhe*),	50	3777	2·0	10 56 56	62° 20′ 41″ n.
223	Ursa Major,	φ,	52	3812	3·1	11 3 29	45° 5′ 39″ n.
224	Leo,	δ (*Zosma*),	68	3834	2·8	11 8 15	21° 7′ 34″ n.
225	Leo,	θ,	70	3838	3·5	11 8 28	16° 1′ 57″ n.
226	Ursa Major,	ξ,	53	3851	3·8	11 12 19	32° 8′ 57″ n.
227	Ursa Major,	ν,	54	3852	3·8	11 12 33	33° 41′ 41″ n.
228	Crater,	δ,	12	3859	3·9	11 13 51	14° 11′ 0″ s.
229	Leo,	ι,	78	3877	4·0	11 18 12	11° 8′ 10″ n.
230	Draco,	λ (*Júza*),	1	3914	4·1	11 24 52	69° 56′ 16″ n.
231	Centaurus,	λ,	...	3941	3·5	11 30 43	62° 24′ 40″ s.
232	Ursa Major,	χ,	63	3981	3·9	11 40 15	48° 23′ 22″ n.
233	Leo,	β (*Denebola*),	94	3995	2·2	11 43 27	15° 11′ 13″ n.
234	Virgo,	β (*Zavijava*),	5	4002	3·7	11 44 58	2° 23′ 5″ n.
235	Ursa Major,	γ (*Phecda*),	64	4017	2·6	11 48 3	54° 18′ 23″ n.
236	Centaurus,	δ,	...	4087	2·9	12 2 39	50° 6′ 34″ s.
237	Corvus,	ε,	2	4097	3·1	12 4 28	22° 0′ 28″ s.
238	Crux,	δ,	...	4120	3·5	12 9 18	58° 8′ 13″ s.
239	Ursa Major,	δ (*Megrez*),	69	4123	3·4	12 9 59	57° 38′ 34″ n.
240	Corvus,	γ,	4	4124	2·8	12 10 9	16° 55′ 51″ s.
241	Virgo,	η,	15	4145	4·0	12 14 17	0° 3′ 19″ s.
242	Crux,	α,	...	4187	1·0	12 20 29	62° 29′ 21″ s.
243	Corvus,	δ (*Algorab*),	7	4211	3·1	12 24 11	15° 54′ 11″ s.
244	Crux,	γ,	...	4215	2·0	12 25 4	56° 29′ 48″ s.
245	Corvus,	β,	9	4234	2·8	12 28 36	22° 47′ 18″ s.
246	Musca,	α,	...	4245	3·0	12 30 38	68° 31′ 44″ s.
247	Centaurus,	γ,	...	4264	2·4	12 35 26	48° 21′ 20″ s.
248	Virgo,	γ (*Porrima*),	29	4268	2·8	12 36 5	0° 50′ 44″ s.
249	Musca,	β,	...	4280	3·5	12 39 32	67° 29′ 20″ s.
250	Crux,	β,	...	4289	1·6	12 41 18	59° 5′ 14″ s.
251	Ursa Major,	ε (*Alioth*),	77	4335	1·9	12 49 11	56° 33′ 23″ n.
252	Virgo,	δ,	43	4340	3·7	12 50 4	3° 59′ 43″ n.
253	Canes Venatici,	α (*Cor. Caroli*),	12	4346	3·0	12 50 53	38° 54′ 55″ n.
254	Musca,	δ,	...	4353	3·7	12 54 42	70° 57′ 18″ s.
255	Virgo,	ε (*Vindemiatrix*),	47	4367	3·0	12 56 42	11° 33′ 2″ n.
256	Hydra,	γ,	46	4450	3·4	13 12 57	22° 15′ 24″ s.
257	Centaurus,	ι,	...	4458	3·1	13 14 24	36° 7′ 54″ s.

No.	*CONSTELLATION.*	*Greek or Roman Letter, and Synonym.*	*Flamsteed Number.*	*B.A.C.*	*MAGNITUDE.*	*RIGHT ASCENSION.*	*DECLINATION.*
						h. m. s.	
258	Virgo,	α (*Spica*),	67	4480	1·2	13 19 24	10° 35′ 13″ s.
259	Ursa Major,	ζ (*Mizar*),	79	4484	2·4	13 19 30	55° 29′ 59″ n.
260	Virgo,	ζ,	79	4532	3·5	13 29 5	0° 1′ 59″ s.
261	Centaurus,	ε,	...	4549	2·7	13 32 55	52° 54′ 25″ s.
262	Centaurus,	ν,	...	4601	3·8	13 42 54	41° 8′ 19″ s.
263	Centaurus,	μ,	...	4602	4·5	13 42 59	41° 55′ 30″ s.
264	Ursa Major,	η (*Benetnasch*),	85	4607	2·0	13 43 12	49° 51′ 45″ n.
265	Centaurus,	ζ,	...	4638	2·8	13 48 41	46° 44′ 46″ s.
266	Boötes,	η (*Saak*),	8	4648	2·9	13 49 27	18° 56′ 57″ n.
267	Centaurus,	β,	...	4669	0·8	13 56 4	59° 50′ 31″ s.
268	Hydra,	π,	49	4685	3·5	14 0 6	26° 9′ 4″ s.
269	Centaurus,	θ,	5	4686	2·0	14 0 13	35° 49′ 37″ s.
270	Draco,	α (*Thuban*),	11	4696	3·6	14 1 25	64° 54′ 6″ n.
271	Virgo,	ι (*Syrma*),	99	4727	4·2	14 10 15	5° 28′ 30″ s.
272	Boötes,	α (*Arcturus*),	16	4729	0·1	14 10 39	19° 45′ 20″ n.
273	Boötes,	ϱ,	25	4808	3·6	14 27 5	30° 51′ 16″ n.
274	Centaurus,	η,	...	4811	2·5	14 28 30	41° 40′ 26″ s.
275	Boötes,	γ,	27	4812	3·1	14 27 40	38° 47′ 21″ n.
276 277	Centaurus,	α,	...	4831 4832	0·1	14 32 8	60° 22′ 43″ s.
278	Circinus,	......	...	4835	3·6	14 33 37	64° 29′ 39″ s.
279	Lupus,	α,	...	4839	2·7	14 34 36	46° 54′ 55″ s.
280	Boötes,	ζ,	30	4849	3·8	14 35 54	14° 12′ 3″ n.
281	Virgo,	μ,	107	4855	3·9	14 37 16	5° 10′ 47″ s.
282	Boötes,	ε (*Izar*),	36	4876	2·6	14 40 11	27° 32′ 17″ n.
283	Virgo,	......	109	4878	3·7	14 40 41	2° 21′ 26″ n.
284	Libra,	α,	9	4895	3·0	14 44 48	15° 35′ 3″ s.
285	Lupus,	β,	...	4924	2·9	14 51 20	42° 41′ 24″ s.
286	Centaurus,	ϰ,	...	4928	3·4	14 51 59	41° 39′ 43″ s.
287	Ursa Minor,	β (*Kocab*),	7	4936	2·1	14 51 2	74° 36′ 18″ n.
288	Libra,	γ,	20	4950	3·2	14 57 38	24° 50′ 56″ s.
289	Boötes,	β (*Nekkar*),	42	4958	3·6	14 57 48	40° 49′ 29″ n.
290	Lupus,	ζ,	...	4987	3·7	15 4 22	51° 40′ 47″ s.
291	Triangulum Australe,	γ,	...	5005	3·2	15 8 38	68° 16′ 20″ s.
292	Libra,	β,	27	5034	2·7	15 11 5	8° 58′ 35″ s.
293	Boötes,	δ,	49	5036	3·5	15 11 4	33° 43′ 34″ n.
294	Lupus,	δ,	...	5046	3·6	15 14 8	40° 14′ 55″ s.
295	Ursa Minor,	γ,	13	5094	3·2	15 20 55	72° 13′ 33″ n.
296	Draco,	ι,	12	5097	3·4	15 22 29	59° 21′ 5″ n.
297	Corona Borealis,	β,	3	5098	3·8	15 23 18	29° 29′ 6″ n.
298	Lupus,	γ,	...	5118	3·3	15 27 49	40° 47′ 45″ s.
299	Serpens,	δ,	13	5135	4·0	15 29 33	10° 54′ 25″ n.
300	Corona Borealis,	α (*Alphecca*),	5	5143	2·4	15 30 2	27° 5′ 7″ n.
301	Serpens,	α (*Cor Serpentis*),	24	5196	2·7	15 38 51	6° 46′ 19″ n.
302	Serpens,	β,	28	5216	3·8	15 41 7	15° 46′ 4″ n.
303	Serpens,	μ,	32	5230	3·5	15 43 53	3° 5′ 33″ s.
304	Triangulum Australe,	β,	...	5233	3·2	15 45 27	63° 5′ 21″ s.
305	Serpens,	ϰ,	35	5234	4·2	15 43 48	18° 28′ 58″ n.
306	Serpens,	ε,	37	5245	3·7	15 45 20	4° 48′ 34″ n.
307	Serpens,	γ,	41	5284	4·0	15 51 22	16° 1′ 20″ n.
308	Ursa Minor,	ζ,	16	5285	4·4	15 48 0	78° 7′ 56″ n.
309	Scorpio,	π,	6	5289	3·1	15 52 11	25° 47′ 49″ s.

THE NAMES AND POSITIONS OF THE MORE IMPORTANT STARS, &c.—*continued.*

No.	*CONSTELLATION.*	*Greek or Roman Letter, and Synonym.*	*Flamsteed Number.*	*B.A.C.*	*MAGNITUDE.*	*RIGHT ASCENSION.*	*DECLINATION.*
						h. m. s.	
310	Scorpio, . . .	δ, ...	7	5303	2·5	15 53 50	22° 18′ 27″ N.
311	Scorpio, . . .	β (*Akrab*), . .	8	5329	2·9	15 59 2	19° 30′ 13″ S.
312	Ophiuchus, . .	δ, ...	1	5414	2·8	16 8 35	3° 24′ 37″ S.
313	Ophiuchus, . .	ε, ...	2	5437	3·4	16 12 30	4° 25′ 25″ S.
314	Scorpio, . . .	σ, ...	20	5447	3·0	16 14 30	25° 19′ 41″ S.
315	Hercules, . .	τ, ...	22	5463	3·9	16 16 26	46° 34′ 32″ N.
316	Hercules, . .	γ, ...	20	5466	3·8	16 17 4	19° 24′ 43″ N.
317	Scorpio, . . .	α (*Antares*), . .	21	5498	1·0	16 22 40	26° 11′ 14″ S.
318	Draco, . . .	η, ...	14	5512	2·8	16 22 30	61° 45′ 47″ N.
319	Ophiuchus, . .	λ, ...	10	5520	4·0	16 25 22	2° 13′ 32″ N.
320	Hercules, . .	β (*Korneforos*), .	27	5525	2·8	16 25 29	21° 43′ 50″ N.
321	Scorpio, . . .	τ, ...	23	5539	2·9	16 29 2	27° 59′ 10″ S.
322	Ophiuchus, . .	ζ, ...	13	5548	2·8	16 31 6	10° 20′ 37″ S.
323	Triangulum Australe,	α, ...	...	5578	2·2	16 37 1	68° 49′ 28″ S.
324	Hercules, . .	ζ, ...	40	5604	3·0	16 37 8	31° 48′ 10″ N.
325	Hercules, . .	η, ...	44	5617	3·7	16 39 4	39° 7′ 56″ N.
326	Scorpio, . . .	ε, ...	26	5632	2·2	16 43 3	34° 5′ 31″ S.
327	Scorpio, . . .	μ^1, ...	...	5638	3·3	16 44 25	37° 51′ 28″ S.
328	Scorpio, . . .	μ^2, ...	...	5640		16 44 53	37° 49′ 44″ S.
329	Scorpio, . . .	ζ^2, ...	...	5661	3·6	16 46 50	42° 10′ 17″ S.
330	Ara, . . .	ζ, ...	...	5683	3·3	16 49 30	55° 48′ 56″ S.
331	Ara, . . .	ε^1, ...	...	5697	4·2	16 50 49	52° 58′ 31″ S.
332	Ophiuchus, . .	ϰ, ...	27	5708	3·4	16 52 28	9° 32′ 48″ N.
333	Hercules, . .	ε, ...	58	5731	4·0	16 56 5	31° 5′ 23″ N.
334	Scorpio, . . .	η, ...	...	5778	3·7	17 4 16	43° 5′ 32″ S.
335	Ursa Minor, .	ε, ...	22	5780	4·4	16 57 15	82° 13′ 2″ N.
336	Ophiuchus, . .	η (*Sábik*), . .	35	5781	2·6	17 4 4	15° 35′ 16″ S.
337	Hercules, . .	α (*Ras Algethi*), .	64	5821	3·2	17 9 38	14° 30′ 58″ N.
338	Draco, . . .	ζ, ...	22	5823	3·3	17 8 28	65° 51′ 0″ N.
339	Hercules, . .	δ, ...	65	5828	3·3	17 10 31	34° 58′ 9″ N.
340	Hercules, . .	π, ...	67	5834	3·4	17 11 13	36° 56′ 4″ N.
341	Ara, . . .	γ, ...	...	5850	3·7	17 16 8	56° 16′ 22″ S.
342	Ophiuchus, . .	θ, ...	42	5851	3·4	17 15 15	24° 53′ 20″ S.
343	Ara, . . .	β, ...	...	5852	2·9	17 16 9	55° 25′ 29″ S.
344	Ara, . . .	δ, ...	...	5877	3·8	17 21 10	60° 35′ 26″ S.
345	Ara, . . .	α, ...	...	5899	3·0	17 23 20	49° 47′ 16″ S.
346	Scorpio, . . .	υ, ...	34	5901	2·8	17 23 16	37° 12′ 25″ S.
347	Scorpio, . . .	λ. (*Shauláh*), . .	35	5915	1·7	17 26 8	37° 1′ 22″ S.
348	Scorpio, . . .	θ, ...	...	5935	2·1	17 29 25	42° 55′ 36″ S.
349	Draco, . . .	β (*Alwaid*), . .	23	5937	3·0	17 27 57	52° 22′ 59″ N.
350	Ophiuchus, . .	α (*Ras-al-ague*), .	55	5941	2·2	17 29 50	12° 38′ 26″ N.
351	Serpens, . . .	ξ, ...	55	5949	3·7	17 31 17	15° 19′ 42″ N.
352	Scorpio, . . .	ϰ, ...	...	5970	2·7	17 34 52	38° 58′ 20″ S.
353	Hercules, . .	ι, ...	85	5990	3·9	17 36 23	46° 3′ 55″ N.
354	Ophiuchus, . .	β (*Celbalrai*), .	69	5996	2·9	17 38 2	4° 36′ 50″ N.
355	Scorpio, . . .	ι^1, ...	...	6004	3·4	17 39 52	40° 5′ 0″ S.
356	Scorpio, . . .	G, ...	...	6018	3·5	17 42 22	37° 0′ 26″ S.
357	Ophiuchus, . .	γ, ...	62	6020	3·8	17 42 23	2° 44′ 58″ N.
358	Hercules, . .	μ, ...	86	6021	3·5	17 42 9	27° 47′ 8″ N.
359	Ophiuchus, . .	ν, ...	64	6078	3·5	17 52 58	9° 45′ 33″ S.
360	Draco, . . .	ξ, ...	32	6079	3·9	17 51 38	53° 53′ 23″ N.
361	Hercules, . .	θ, ...	91	6082	4·0	17 52 29	37° 15′ 59″ N.

THE NAMES AND POSITIONS OF THE MORE IMPORTANT STARS, &c.—*continued.*

No.	CONSTELLATION.	Greek or Roman Letter, and Synonym.	Flamsteed Number.	B.A.C.	MAGNITUDE.	RIGHT ASCENSION.	DECLINATION.
						h. m. s.	
362	Hercules,	ξ,	92	6084	3·9	17 53 30	29° 15′ 37″ n.
363	Draco,	γ (*Etanim*),	33	6091	2·4	17 54 3	51° 30′ 7″ n.
364	Sagittarius,	γ,	10	6115	3·0	17 58 45	30° 25′ 31″ s.
365	Ophiuchus,	......	72	6143	3·8	18 2 8	9° 32′ 54″ n.
366	Hercules,	ο,	103	6150	4·0	18 3 15	28° 44′ 54″ n.
367	Sagittarius,	μ,	13	6168	4·0	18 7 11	21° 5′ 13″ s.
368	Sagittarius,	η,	...	6186	3·0	18 10 11	36° 47′ 36″ s.
369	Sagittarius,	δ,	19	6209	2·8	18 13 57	29° 52′ 31″ s.
370	Serpens,	η,	58	6229	3·4	18 15 37	2° 55′ 36″ s.
371	Sagittarius,	ε (*Kaus Australis*),	20	6233	2·1	18 16 52	34° 26′ 8″ s.
372	Telescopium,	α,	...	6240	3·6	18 18 49	46° 1′ 40″ s.
373	Sagittarius,	λ,	22	6263	3·1	18 21 11	25° 28′ 55″ s.
374	Ursa Minor,	δ,	23	6281	4·3	18 7 48	86° 36′ 41″ n.
375	Draco,	χ,	44	6302	3·7	18 23 3	72° 41′ 10″ n.
376	Octans,	σ,	...	5959	5·5	18 42 22	89° 16′ 1″ s.
377	Lyra,	α (*Vega*),	3	6355	0·2	18 33 13	38° 40′ 54″ n.
378	Sagittarius,	ψ,	27	6371	3·3	18 38 47	27° 6′ 13″ s.
379	Lyra,	β (*Sheliak*),	10	6429	3·6	18 46 1	33° 14′ 7″ n.
380	Sagittarius,	σ,	34	6440	2·3	18 48 27	26° 25′ 58″ s.
381	Sagittarius,	ξ,	37	6461	3·5	18 51 10	21° 15′ 1″ s.
382	Aquila,	ε,	13	6487	4·1	18 54 38	14° 55′ 9″ n.
383	Sagittarius,	ζ,	38	6489	2·9	18 55 37	30° 2′ 14″ s.
384	Lyra,	γ (*Sulaphat*),	14	6491	3·3	18 54 50	32° 32′ 23″ n.
385	Sagittarius,	ο,	39	6507	3·9	18 58 5	21° 54′ 4″ s.
386	Sagittarius,	τ,	40	6521	3·5	19 0 5	27° 49′ 50″ s.
387	Aquila,	λ,	16	6526	3·6	19 0 25	5° 2′ 51″ s.
388	Aquila,	ζ,	17	6528	3·1	19 0 21	13° 42′ 2″ n.
389	Sagittarius,	π,	41	6548	3·1	19 3 13	21° 11′ 52″ s.
390	Sagittarius,	β^1,	...	6608	3·9	19 14 44	44° 39′ 51″ s.
391	Sagittarius,	β^2,	...	6610	4·4	19 15 16	45° 0′ 21″ s.
392	Draco,	δ (*Taïs*),	57	6612	3·2	19 12 32	67° 28′ 4″ n.
393	Sagittarius,	α,	...	6622	4·0	19 16 16	40° 49′ 18″ s.
394	Sagittarius,	ϱ,	44	6619	3·9	19 15 18	18° 3′ 9″ s.
395	Cygnus,	ϰ,	1	6623	3·9	19 14 34	53° 9′ 53″ n.
396	Aquila,	δ,	30	6646	3·5	19 19 57	2° 53′ 46″ n.
397	Cygnus,	β (*Abbireo*),	6	6690	3·0	19 26 17	37° 43′ 47″ n.
398	Cygnus,	ι,	10	6697	3·9	19 26 56	51° 29′ 43″ n.
399	Sagitta,	α,	5	6739	4·3	19 35 11	17° 45′ 45″ n.
400	Aquila,	γ (*Tarazed*),	50	6772	2·8	19 41 2	10° 20′ 44″ n.
401	Cygnus,	δ,	18	6779	3·0	19 41 32	44° 51′ 42″ n.
402	Sagitta,	δ,	7	6783	3·7	19 42 30	18° 15′ 51″ n.
403	Aquila,	α (*Altair*),	53	6802	1·0	19 45 25	8° 34′ 42″ n.
404	Aquila,	η,	55	6811	3·9	19 46 52	0° 43′ 24″ n.
405	Aquila,	β (*Alshain*),	60	6833	4·0	19 49 55	6° 7′ 56″ n.
406	Draco,	ε,	63	6836	3·9	19 48 32	69° 59′ 15″ n.
407	Pavo,	δ,	...	6873	3·6	19 57 54	66° 27′ 30″ s.
408	Sagitta,	γ,	12	6858	3·6	19 53 52	19° 11′ 42″ n.
409	Aquila,	θ,	65	6934	3·4	20 5 38	1° 8′ 50″ s.
410	Cygnus,	o^1,	31	6965	3·8	20 10 10	46° 24′ 32″ n.
411	Capricornus,	α^1 } (*Säd-adh-* }	5	6972	4·5	20 11 33	12° 50′ 50″ s.
412	Capricornus,	α^2 } *dhabih*), }	6	6974	3·8	20 11 57	12° 53′ 7″ s.
413	Capricornus,	β,	9	6995	3·4	20 14 50	15° 7′ 40″ s.

THE NAMES AND POSITIONS OF THE MORE IMPORTANT STARS, &c.—*continued.*

No.	*CONSTELLATION.*	*Greek or Roman Letter, and Synonym.*	*Flamsteed Number.*	*B.A.C.*	*MAGNITUDE.*	*RIGHT ASCENSION.*	*DECLINATION.*
						h. m. s.	
414	Pavo,	α,	...	7004	2·1	20 16 56	57° 5′ 11″ s.
415	Cygnus,	γ,	37	7022	2·3	20 18 17	39° 54′ 18″ n.
416	Delphinus,	ε,	2	7088	4·0	20 27 57	10° 55′ 47″ n.
417	Indus,	α,	...	7096	3·2	20 29 50	47° 40′ 29″ s.
418	Delphinus,	β (*Rotaner*),	6	7121	3·7	20 32 23	14° 12′ 49″ n.
419	Pavo,	β,	...	7129	3·4	20 35 3	66° 35′ 52″ s.
420	Delphinus,	α (*Svalocin*),	9	7149	3·9	20 34 32	15° 31′ 28″ n.
421	Cygnus,	α (*Arided*),	50	7171	1·5	20 37 41	44° 53′ 15″ n.
422	Aquarius,	ε,	2	7196	3·8	20 41 43	9° 53′ 52″ s.
423	Delphinus,	γ,	12	7200	4·0	20 41 33	15° 43′ 46″ n.
424	Cygnus,	ε,	53	7204	2·7	20 41 46	33° 33′ 31″ n.
425	Cepheus,	η,	3	7220	3·6	20 43 3	61° 24′ 43″ n.
426	Indus,	β,	...	7228	3·8	20 46 13	58° 52′ 6″ s.
427	Cygnus,	ν,	58	7277	4·0	20 53 4	40° 44′ 40″ n.
428	Cygnus,	ξ,	62	7333	3·7	21 0 55	43° 29′ 28″ n.
429	Cygnus,	ζ,	64	7368	3·5	21 8 15	29° 46′ 33″ n.
430	Cepheus,	α (*Alderamin*),	5	7416	2·6	21 15 57	62° 7′ 10″ n.
431	Capricornus,	ζ,	34	7445	3·8	21 20 23	22° 53′ 12″ s.
432	Aquarius,	β (*Sadalsuud*),	22	7478	3·1	21 25 46	6° 3′ 17″ s.
433	Cepheus,	β (*Alpirk*),	8	7493	3·4	21 27 14	70° 4′ 39″ n.
434	Capricornus,	γ (*Deneb Algedi*),	40	7525	3·8	21 34 0	27° 9′ 29″ s.
435	Pegasus,	ε (*Enif*),	8	7561	2·4	21 38 47	9° 22′ 15″ n.
436	Capricornus,	δ,	49	7580	3·0	21 40 58	26° 37′ 30″ s.
437	Grus,	γ,	...	7613	3·1	21 47 16	37° 52′ 54″ s.
438	Aquarius,	α (*Sadalmelik*),	34	7688	3·2	22 0 8	0° 51′ 14″ s.
439	Grus,	α,	...	7692	1·8	22 1 18	47° 29′ 36″ s.
440	Pegasus,	ι,	24	7706	4·0	22 1 53	24° 48′ 31″ n.
441	Pegasus,	θ,	26	7723	3·8	22 11 2	8° 19′ 51″ s.
442	Cepheus,	ζ,	21	7749	3·5	22 7 2	57° 39′ 32″ n.
443	Toucan,	α,	...	7767	2·9	22 10 58	60° 48′ 27″ s.
444	Aquarius,	γ (*Sadachbia*),	48	7795	4·0	22 15 58	1° 56′ 28″ s.
445	Aquarius,	ζ,	55	7832	3·8	22 23 10	0° 34′ 56″ s.
446	Piscis Australis,	β,	17	7842	4·3	22 25 15	32° 54′ 36″ s.
447	Lacerta,	......	7	7855	3·9	22 26 46	49° 42′ 59″ n.
448	Aquarius,	η,	62	7868	4·2	22 29 42	0° 41′ 3″ s.
449	Piscis Australis,	ε,	18	7898	4·0	22 34 34	27° 43′ 15″ s.
450	Grus,	β,	...	7904	2·2	22 36 5	47° 27′ 33″ s.
451	Pegasus,	ζ (*Homan*),	42	7908	3·6	22 35 58	10° 15′ 26″ n.
452	Pegasus,	η,	44	7923	3·1	22 37 51	29° 38′ 47″ n.
453	Grus,	ε,	...	7946	3·6	22 41 54	51° 53′ 42″ s.
454	Pegasus,	μ,	48	7958	3·7	22 44 42	24° 1′ 18″ n.
455	Cepheus,	ι,	32	7967	3·6	22 45 46	65° 37′ 20″ n.
456	Aquarius,	λ,	73	7970	3·8	22 46 52	8° 9′ 53″ s.
457	Aquarius,	δ,	76	7980	3·4	22 48 49	16° 21′ 17″ s.
458	Piscis Australis,	α (*Fomalhaut*),	24	7992	1·3	22 51 34	30° 12′ 19″ s.
459	Andromeda,	ο,	1	8023	3·8	22 56 52	41° 44′ 10″ n.
460	Pegasus,	β (*Scheat*),	53	8032	2·6	22 58 26	27° 29′ 13″ n.
461	Pegasus,	α (*Markab*),	54	8034	2·6	22 59 17	14° 36′ 49″ n.
462	Aquarius,	c^2,	88	8062	3·6	23 3 35	21° 46′ 10″ s.
463	Pisces,	γ,	6	8105	3·8	23 11 28	2° 40′ 52″ n.
464	Cepheus,	γ (*Alrai*),	35	8238	3·4	23 34 50	77° 1′ 6″ n.

INDEX TO CHART OF THE MOON.

LUNAR MOUNTAINS.

Alps	Cd
Altai Mountains	Ba
Apennines	Cc
Carpathian Mts.	Cc
Caucasus	Bd
Corderillas	Db
D'Alembert Mts.	Db
Doerfel Mountains	Ca
Hemus Mountains	Bc
Hercynien Mts.	Dc
Leibnitz Mts.	Ba
Mont Blanc	Bd
Pyrenees	Ab
Riphees Mts.	Cb
Rook Mountains	Db
Taurus Mts.	Ad

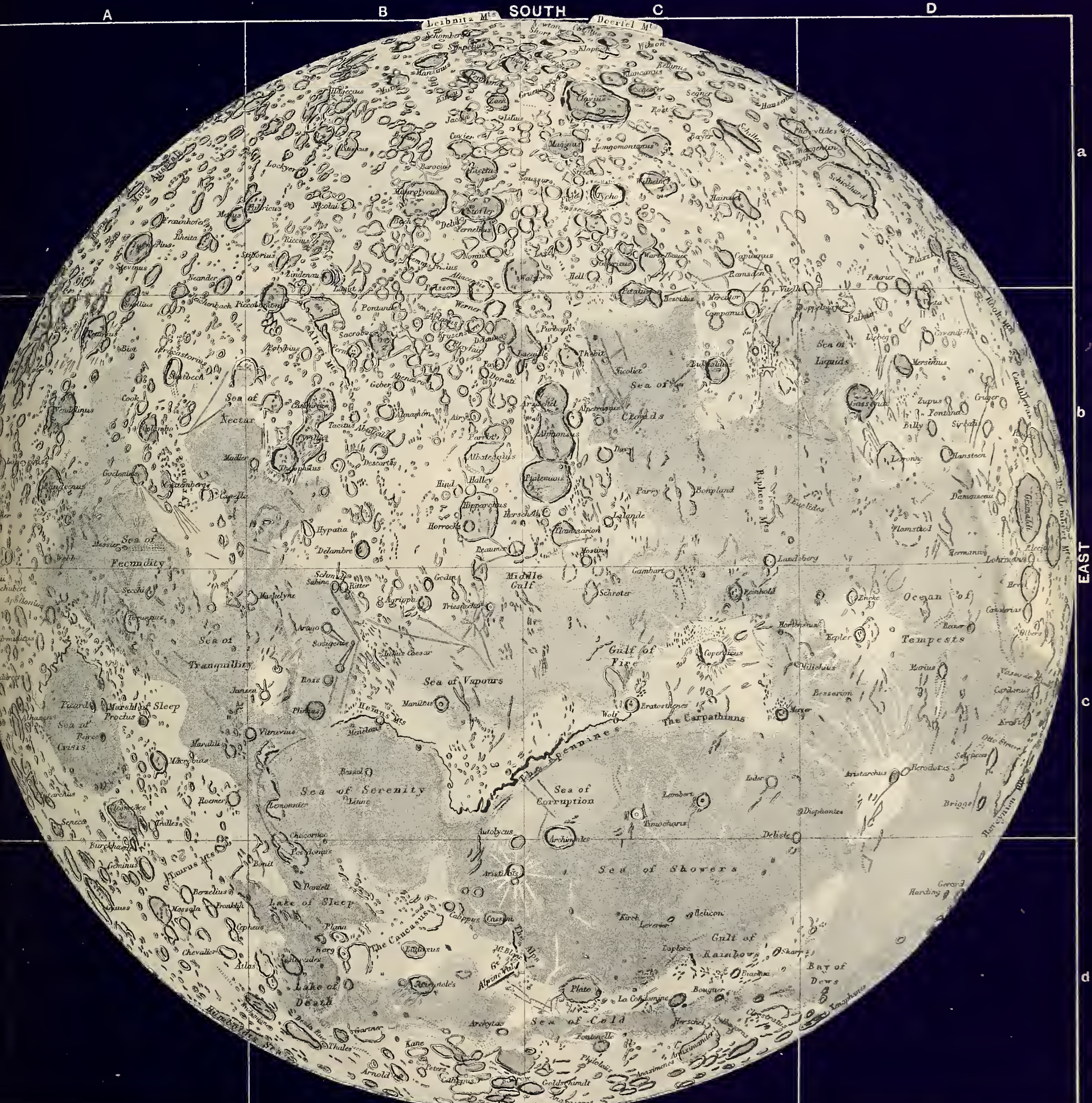
LUNAR SEAS, GULFS, &C.

Bay of Dews	Dd
Bay of Rainbows	Cd
Great Alpine Valley	Bd
Gulf of Fire	Cc
Humboldt's Sea	Ad
Lake of Death	Bd
„ Sleep	Bd
Mare Australe	Aa
Marsh of Sleep	Ac
Middle Gulf	Cc
Ocean of Tempests	Dc
Sea of Clouds	Cb
„ Cold	Cd
„ Corruption	Cc
„ Crisis	Ac
„ Fecundity	Ab
Sea of Liquids	Db
„ Nectar	Ab
„ Serenity	Bc
„ Showers	Cd
„ Tranquillity	Ac
„ Vapours	Bc
Smyth Sea	Ab

LUNAR CRATERS.

Abenezra	Bb
Abulfeda	Ba
Agrippa	Bc
Airy	Bb
Alds	Bd
Alhazen	Ac
Albategnius	Ba
Aliacensis	Ba
Almanon	Ba
Alpetragius	Cb
Alphonsus	Cb
Anaxagoras	Cd
Anaximander	Cd
Anaximenes	Cd
Apianus	Bb
Appollonius	Ac
Arago	Bc
Archimedes	Cd
Archytas	Bd
Aristarchus	Dc
Aristillus	Bd
Aristoteles	Bd
Arnold	Bd
Arzachel	Cb
Atlas	Bd
Autolycus	Bd
Bacon	Ba
Barocius	Ba
Barrow	Bd
Bayer	Ca
Bellinus	Ca
Berzelius	Ad
Bessarion	Dc
Bessel	Bc
Biachini	Cd
Billy	Db
Biot	Ab
Blancanus	Ca
Bonito	Cd
Bonpland	Cb
Bouguer	Cd
Briggs	Dc
Bullialdus	Cb
Burckhardt	Ad
Buch	Ba
Burg	Bd
Calippus	Bd
Campanus	Cb
Capella	Ab
Capuanus	Ca
Cardanus	Dc
Casatus	Ca
Cassini	Bd
Cathcarina	Bb
Cavalerius	Dc
Cavendish	Db
Cepheus	Ad
Certius	Ba
Chacornac	Bc
Chevalier	Ad
Clavius	Ca
Cleomedes	Ac
Cleostratus	Cd
Colombo	Ab
Condurcet	Ac
Cook	Ab
Copernicus	Cc
Cruger	Db
Cuvier	Ba
Cyrillies	Bb
Damoiseau	Db
Daniell	Bd
Davy	Cb
Delambre	Bb
De la Rue	Bd
Delaunay	Bb
Delisle	Cd
Deluc	Ba
Descartes	Bb
Diophantes	Dc
Donati	Bb
Doppelmayer	Db
Encke	Dc
Endymion	Bd
Eratosthenes	Cc
Euclides	Cb
Eudoxus	Bd
Euler	Cc
Fabricus	Ba
Faye	Bb
Fermat	Bb
Fernelius	Ba
Firminicus	Ac
Flammarion	Cb
Flamsteed	Db
Fontana	Db
Fontenelle	Cd
Fourier	Da
Fracastorius	Ab
Franklin	Ad
Fraunhofer	Aa
Gambart	Cc
Gartner	Bd
Gassendi	Db
Gauricus	Ca
Gauss	Ad
Geber	Bb
Gemma Frisius	Ba
Geminus	Ad
Gerard	Dd
Godin	Bc
Goldsmidt	Cd
Grimaldi	Db
Gruemberger	Ca
Guttemberg	Ab
Hagecius	Ba
Hainzel	Ca
Halley	Bb
Hansen	Ca
Hansteen	Db
Harding	Dd
Helicon	Cd
Hell	Ca
Hercules	Bd
Herodotus	Dc
Hermann	Db
Herschel	Cb
Herschel	Cd
Hesoidus	Cb
Hevel	Dc
Hevelius	Dc
Hind	Bb
Hipparchus	Bb
Horrocks	Bb
Hortensius	Cc
Hypatia	Bb
Inghirami	Da
Jacobi	Ba
Jansen	Bc
Julius Cæsar	Bc
Kane	Bd
Kepler	Dc
Kicestner	Ab
Kinau	Ba
Kirch	Cd
Kirminicus	Ac
Klapreth	Ba
Kraft	Dc
Krustern	Bb
Lacaille	Cb
La Condamine	Cb
Lagrange	Da
Lagut	Ba
Lalande	Cb
Lambert	Cc
Landsberg	Cb
Langrenus	Ab
Lapeyrouse	Ab
Laplace	Cd
Laxell	Ca
Legendre	Ab
Lemonnier	Bc
Leronne	Db
Leverier	Cd
Licetus	Ba
Liebeg	Db
Lilius	Ba
Lindenau	Ba
Linne	Bc
Lockyer	Ba
Lohrmann	Db
Longomontanus	Ca
Macrobrius	Ac
Madler	Bb
Maginus	Ca
Manilius	Bc
Manzinus	Ba
Maraldi	Ac
Marius	Dc
Marnus	Aa
Maskelyne	Bc
Maurotychus	Ab
Mayer	Cc
Menelaus	Bc
Mercator	Cb
Mersenius	Db
Messala	Ad
Messier	Ab
Metius	Aa
Milichius	Dc
Moretus	Ca
Mosting	Cb
Mutus	Ba
Nasmyth	Ca
Newton	Ca
Neander	Aa
Newton	Ca
Nicollet	Cb
Nicolai	Ba
Nonus	Ba
Oken	Aa
Olbers	Dc
Otto Struve	Dc
Palmieri	Db
Parrot	Bb
Parry	Cb
Peirce	Ac
Pentland	Ba
Petarius	Ab
Peters	Bd
Phillips	Ab
Philolaüs	Cd
Phocylides	Da
Piazzi	Da
Picard	Ac
Piccolomini	Bb
Pictet	Ca
Pitatus	Ca
Pitiscus	Ba
Plana	Bd
Plato	Cd
Playfair	Bb
Plinius	Bc
Plutarchus	Ac
Poisson	Ba
Polybius	Bb
Pontanus	Bb
Posidonius	Cd
Proclus	Ac
Ptolemäus	Cb
Purbach	Cb
Pythagoras	Cd
Ramsden	Ca
Reaumer	Bb
Reichenbach	Aa
Reiner	Dc
Reinhold	Cc
Rheita	Aa
Riccioli	Db
Riccius	Ba
Ritter	Bc
Rocca	Db
Roemer	Ac
Ross	Bc
Rost	Ca
Sabine	Bc
Sacrobosco	Bb
Santbech	Ab
Sasserides	Ca
Saussure	Ca
Scheiner	Ca
Schickhard	Da
Schiller	Ca
Schmidt	Bc
Schomberg	Ba
Schroter	Cc
Schubert	Ac
Scoresby	Bd
Secchi	Ac
Segner	Ca
Seleucus	Dc
Seneca	Ac
Sharp	Cd
Short	Ca
Simpelius	Ba
Sirsadis	Db
Smythi	Ac
Snellius	Ab
Sosigenes	Bc
Stevinus	Aa
Stiborius	Ba
Stofler	Ba
Street	Ca
Tacitus	Bb
Thales	Bd
Thebit	Cb
Theophilus	Bb
Timocharis	Cc
Tralles	Ac
Triesnecker	Bc
Trouvelot	Db
Turnerius	Aa
Turuntius	Ac
Tycho	Ca
Vasco di Gama	Dc
Vendelinus	Ab
Vieta	Db
Vitello	Da
Vitruvius	Bc
Vlacq	Ba
Walter	Ca
Wargentin	Da
Warzelbauer	Ca
Webb	Ab
Werner	Bb
Wilhelm I.	Ca
Wilson	Ca
Wolf	Cc
Xenophanes	Dd
Zach	Ba
Zupus	Db

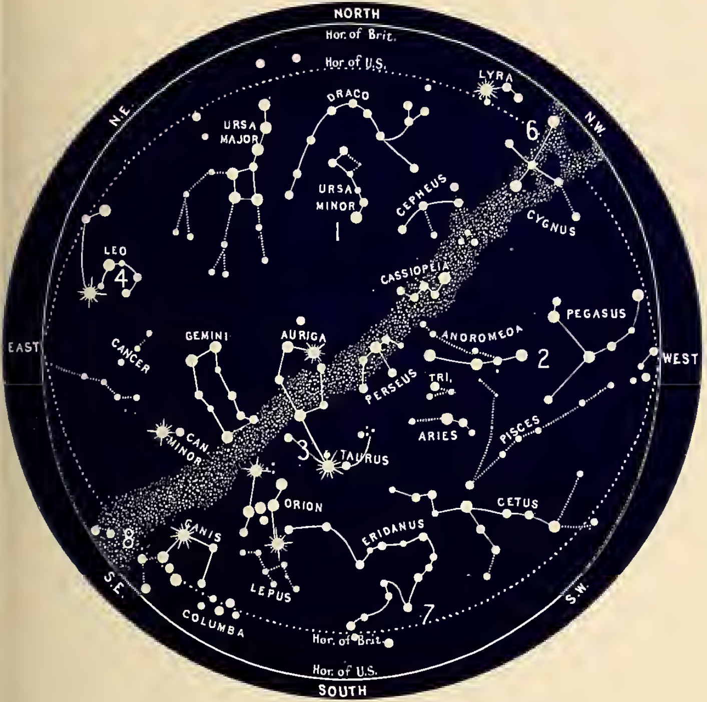
CHART OF THE MOON.


A
B
SOUTH
C
D
Leibnitz Mts
Doerfel Mt
a
b
EAST
c
d
Newton
Short
Schomberger
Simpelius
Manzinus
Moretus
Clavius
Blancanus
Scheiner
Rost
Bayer
Schiller
Bailly
Segner
Wilson
Phocylides
Wargentin
Inghirami
Schickhard
Hainzel
Tycho
Longomontanus
Maginus
Wilhelm I
Street
Saussure
Pictet
Heinsius
Orontius
Nasireddin
Huggins
Stöfler
Faraday
Maurolycus
Barocius
Cuvier
Jacobi
Lilius
Licetus
Nicolaus
Fabricius
Metius
Lockyer
Fraunhofer
Furnerius
Stevinus
Rheita
Neander
Steinheil
Piccolomini
Reichenbach
Riccius
Stiborius
Lindenau
Zagut
Rabbi Levi
Gemma Frisius
Nonius
Walther
Aliacensis
Werner
Poisson
Pontanus
Apian
Kaiser
Blanchinus
Sacrobosco
Playfair
Krusenstern
Lacaille
Purbach
Thebit
Nicollet
Pitatus
Hesiodus
Wurzelbauer
Gauricius
Hell
Capuanus
Ramsden
Mercator
Campanus
Vitello
Doppelmayer
Fourier
Palmieri
Liebig
Mersenius
Cavendish
Gassendi
Zupus
Fontana
Billy
Gruger
Sirsalis
Hansteen
Letronne
Damoiseau
Grimaldi
Flamsteed
Hermann
Lohrmann
Riccioli
Rook Mts
Cordilleras
D'Alembert Mts
Sea of Liquids
Bullialdus
Sea of Clouds
Alpetragius
Arzachel
Alphonsus
Ptolemaeus
Albategnius
Parrot
Halley
Hind
Hipparchus
Herschel
Horrocks
Flammarion
Mösting
Lalande
Parry
Bonpland
Euclides
Riphaen Mts
Landsberg
Gambart
Reinhold
Encke
Kepler
Hortensius
Ocean of Tempests
Marius
Milichius
Bessarion
Copernicus
Gulf of Fire
Schröter
Middle Gulf
Reaumur
Godin
Triesnecker
Agrippa
Ritter
Sabine
Schmidt
Delambre
Hypatia
Sea of Nectar
Catharina
Cyrillus
Theophilus
Madler
Isidorus
Capella
Gutenberg
Goclenius
Colombo
Cook
Vendelinus
Langrenus
Sea of Fecundity
Messier
Secchi
Taruntius
Maskelyne
Arago
Sosigenes
Julius Caesar
Sea of Tranquillity
Ross
Jansen
Plinius
Sea of Vapours
Manilius
Haemus Mts
Menelaus
Vitruvius
Maraldi
Macrobius
Proclus
Marsh of Sleep
Picard
Sea of Crisis
Peirce
Cleomedes
Tralles
Römer
Le Monnier
Sea of Serenity
Bessel
Linné
The Apennines
Sea of Corruption
Eratosthenes
Wolf
The Carpathians
Mayer
Euler
Lambert
Timocharis
Archimedes
Autolycus
Aristillus
Sea of Showers
Diophantus
Delisle
Aristarchus
Herodotus
Brigge
Harding
Gerard
Seleucus
Krafft
Cardanus
Otto Struve
Olbers
Vasco de Gama
Hercynian Mts
Chacornac
Posidonius
Bond
Daniell
Lake of Sleep
Taurus Mts
Berzelius
Franklin
Messala
Geminus
Burckhardt
Cepheus
Chevallier
Atlas
Hercules
Lake of Death
Burg
Plana
The Caucasus
Calippus
Cassini
Eudoxus
Aristoteles
The Alps
Alpine Vall.
Kirch
Leverrier
Helicon
Gulf of Rainbows
Laplace
Sharp
Bianchini
Bay of Dews
Plato
La Condamine
Bouguer
Maupertuis
Sea of Cold
Archytas
Fontenelle
Philolaus
Anaximenes
Anaximander
Harpalus
Horrebow
Gartner
Thales
Kane
Strabo
Peters
Arnold
Gioja
Goldschmidt
Anaxagoras
Humboldt Sea
Endymion
Gauss
Seneca
NORTH

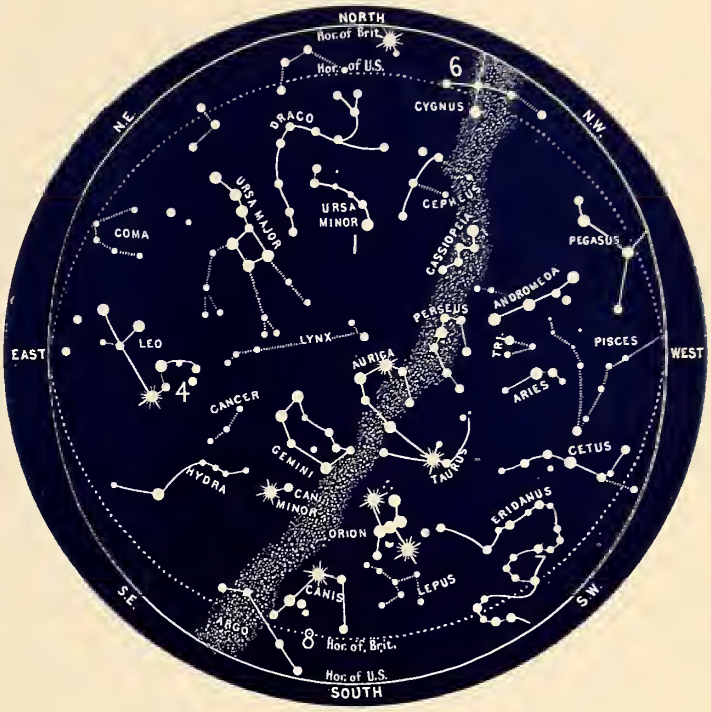
Peck, Delt. Engraved by Archibald & Peck, Edinburgh. Galt & Inglis, Edinburgh.

Maps for the Northern Hemisphere.

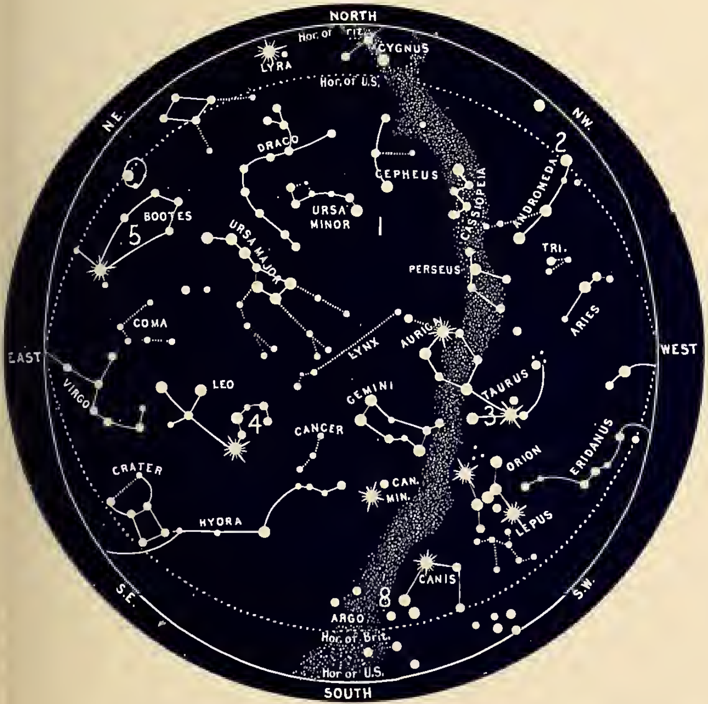
No. 1


NORTH
Hor. of Brit.
Hor. of U.S.
LYRA
DRACO
URSA MAJOR
URSA MINOR
1
CEPHEUS
6
CYGNUS
N.E.
N.W.
LEO
4
CASSIOPEIA
PEGASUS
EAST
CANCER
GEMINI
AURIGA
ANDROMEDA
2
WEST
PERSEUS
TRI.
ARIES
PISCES
CAN. MINOR
3
TAURUS
ORION
CETUS
ERIDANUS
8
CANIS
LEPUS
S.E.
COLUMBA
7
S.W.
Hor. of Brit.
Hor. of U.S.
SOUTH

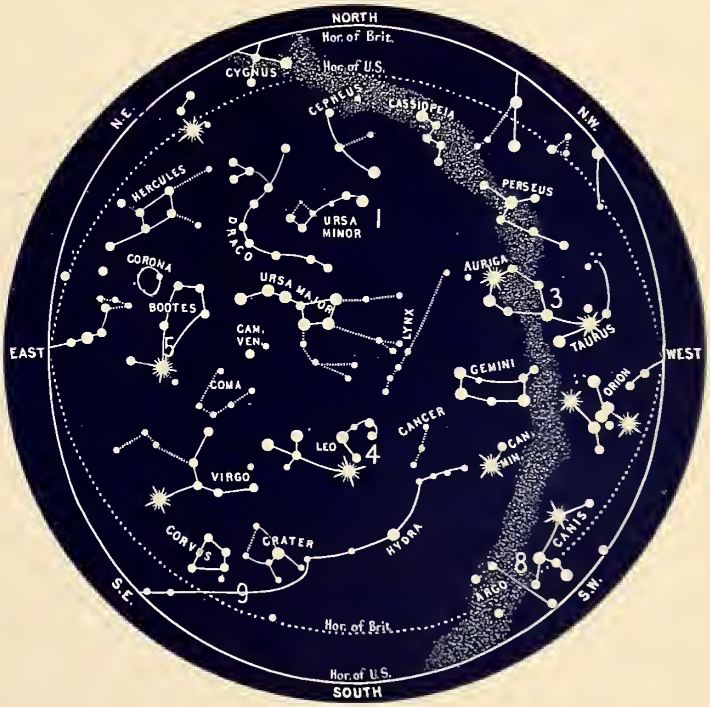
No. 2


NORTH
Hor. of Brit.
Hor. of U.S.
6
CYGNUS
N.E.
N.W.
DRACO
URSA MAJOR
URSA MINOR
1
CEPHEUS
COMA
CASSIOPEIA
PEGASUS
ANDROMEDA
PERSEUS
LYNX
EAST
LEO
4
AURIGA
TRI.
PISCES
WEST
ARIES
CANCER
GEMINI
TAURUS
HYDRA
CETUS
CAN. MINOR
ERIDANUS
ORION
7
S.E.
CANIS
LEPUS
S.W.
ARGO
8
Hor. of Brit.
Hor. of U.S.
SOUTH

No. 3


NORTH
Hor. of Brit.
LYRA
CYGNUS
Hor. of U.S.
N.E.
N.W.
DRACO
2
CEPHEUS
ANDROMEDA
CASSIOPEIA
BOOTES
5
URSA MINOR
1
URSA MAJOR
TRI.
PERSEUS
COMA
ARIES
EAST
WEST
LYNX
AURIGA
VIRGO
LEO
GEMINI
TAURUS
4
CANCER
3
ORION
ERIDANUS
CRATER
CAN. MIN.
LEPUS
HYDRA
S.E.
S.W.
CANIS
8
ARGO
Hor. of Brit.
Hor. of U.S.
SOUTH

No. 4


NORTH
Hor. of Brit.
CYGNUS
Hor. of U.S.
CEPHEUS
CASSIOPEIA
N.E.
N.W.
HERCULES
DRACO
URSA MINOR
1
PERSEUS
CORONA
URSA MAJOR
AURIGA
BOOTES
3
LYNX
CAM. VEN.
TAURUS
EAST
WEST
5
GEMINI
ORION
COMA
CANCER
LEO
4
CAN. MIN.
VIRGO
CANIS
CORVUS
CRATER
HYDRA
8
ARGO
S.E.
9
S.W.
Hor. of Brit.
Hor. of U.S.
SOUTH

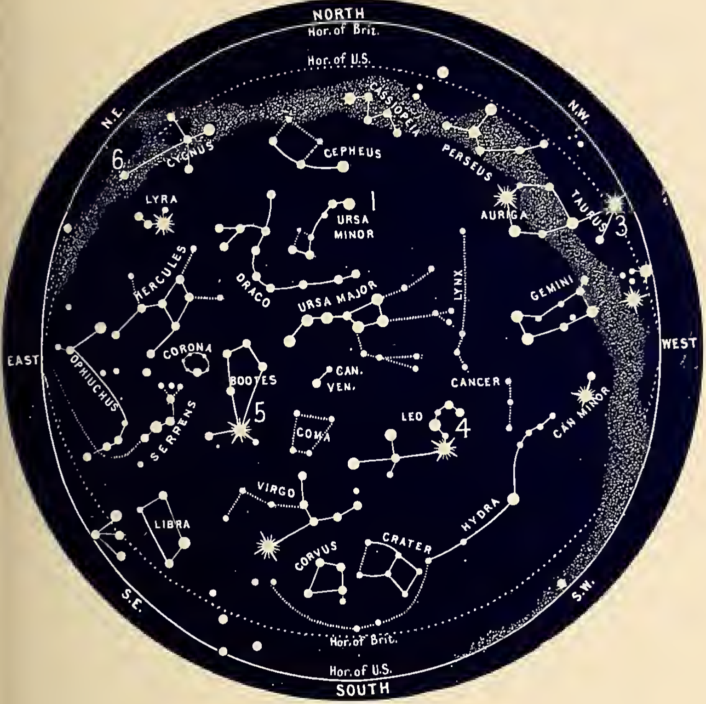
Each of the above Circular Maps is a true representation of the configurations of the principal Stars at the dates and hours given in Table 5 on pages 122 and 123.

The centre of the Map is the point overhead, or the *zenith* of the observer; while the *horizon*, containing the principal compass points, is indicated by the circular line near the circumference. The horizon of Britain (in the Maps *Hor. of Brit.*) includes the horizon for Central Europe and Canada; and the horizon of the United States (in the Maps *Hor. of U.S.*) the horizon for Southern Europe.

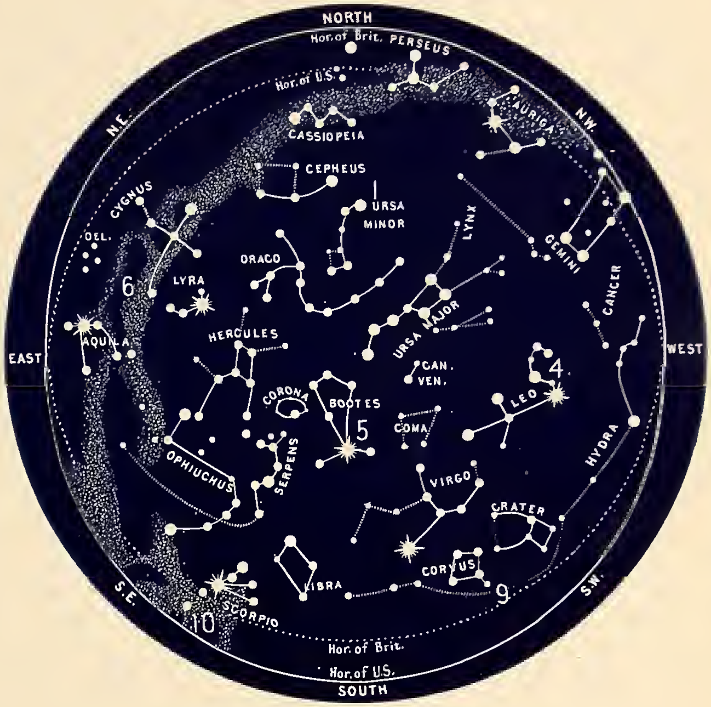
The large numbers inside the Maps are for facilitating the use of the twelve square Star Charts, each number indicating the position in the sky, of the centre of its corresponding Chart.

Maps for the Northern Hemisphere.

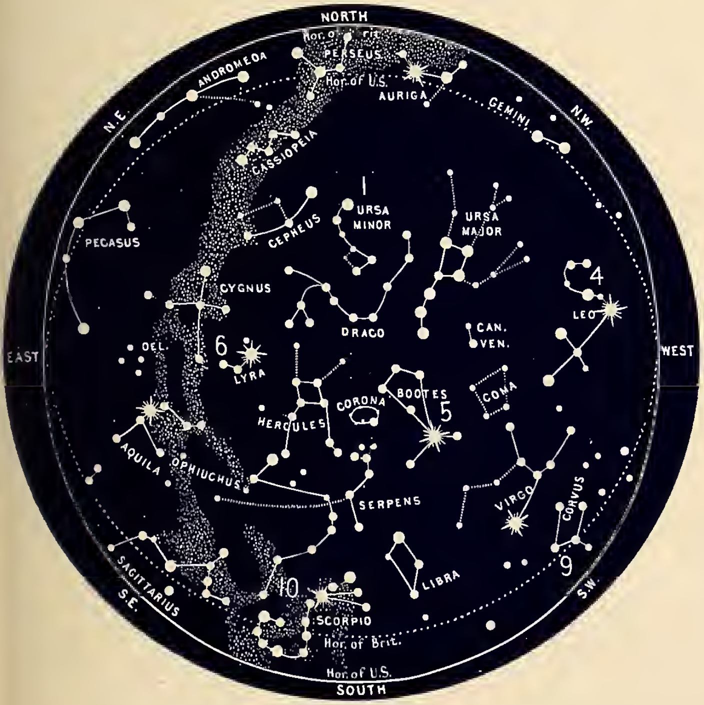
No. 5


NORTH
Hor. of Brit.
Hor. of U.S.
N.E.
NW.
CASSIOPEIA
CYGNUS
6
CEPHEUS
PERSEUS
LYRA
1
URSA MINOR
AURIGA
TAURUS
3
HERCULES
DRACO
URSA MAJOR
LYNX
GEMINI
EAST
WEST
OPHIUCHUS
CORONA
BOOTES
CAN. VEN.
CANCER
SERPENS
5
COMA
LEO
4
CAN MINOR
VIRGO
LIBRA
HYDRA
CORVUS
CRATER
S.E.
S.W.
Hor. of Brit.
Hor. of U.S.
SOUTH

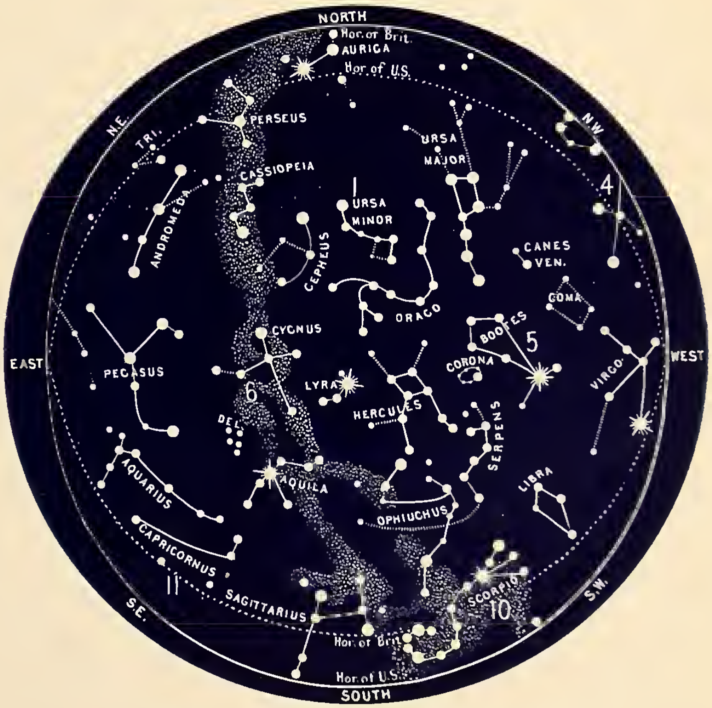
No. 6


NORTH
Hor. of Brit.
PERSEUS
Hor. of U.S.
N.E.
NW.
AURIGA
CASSIOPEIA
CEPHEUS
CYGNUS
1
URSA MINOR
LYNX
DEL.
GEMINI
DRACO
CANCER
6
LYRA
URSA MAJOR
AQUILA
HERCULES
EAST
WEST
CAN. VEN.
4
CORONA
BOOTES
LEO
5
COMA
OPHIUCHUS
SERPENS
HYDRA
VIRGO
CRATER
CORVUS
LIBRA
9
S.E.
S.W.
10
SCORPIO
Hor. of Brit.
Hor. of U.S.
SOUTH

No. 7


NORTH
Hor. of Brit.
PERSEUS
Hor. of U.S.
ANDROMEDA
AURIGA
GEMINI
N.E.
NW.
CASSIOPEIA
PEGASUS
1
URSA MINOR
URSA MAJOR
CEPHEUS
CYGNUS
4
LEO
DRACO
CAN. VEN.
EAST
DEL.
6
LYRA
WEST
HERCULES
CORONA
BOOTES
5
COMA
AQUILA
OPHIUCHUS
SERPENS
VIRGO
CORVUS
9
LIBRA
SAGITTARIUS
10
SCORPIO
S.E.
S.W.
Hor. of Brit.
Hor. of U.S.
SOUTH

No. 8


NORTH
Hor. of Brit.
AURIGA
Hor. of U.S.
N.E.
NW.
TRI.
PERSEUS
URSA MAJOR
CASSIOPEIA
4
ANDROMEDA
1
URSA MINOR
CEPHEUS
CANES VEN.
COMA
DRACO
CYGNUS
BOOTES
5
EAST
PEGASUS
6
LYRA
CORONA
VIRGO
WEST
DEL.
HERCULES
SERPENS
AQUILA
AQUARIUS
LIBRA
OPHIUCHUS
CAPRICORNUS
11
SAGITTARIUS
SCORPIO
10
S.E.
S.W.
Hor. of Brit.
Hor. of U.S.
SOUTH

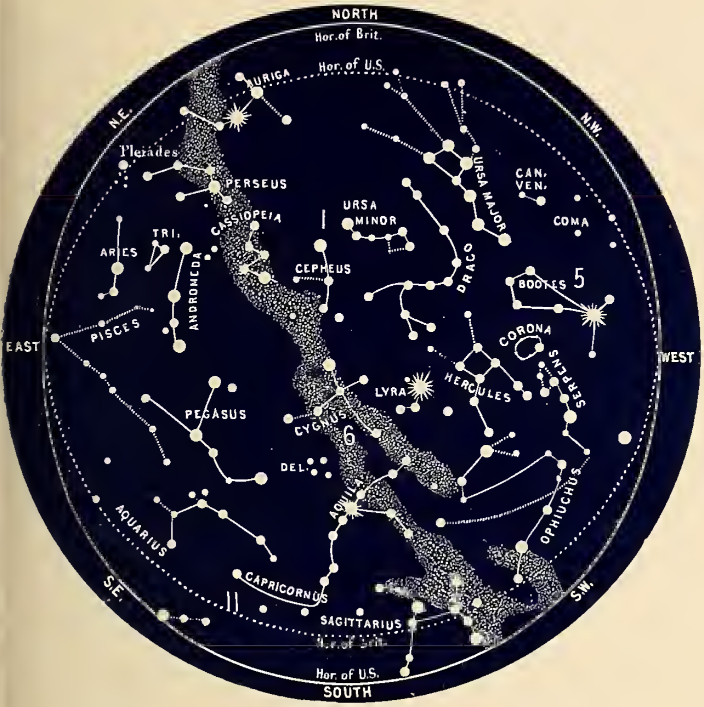
Each of the above Circular Maps is a true representation of the configurations of the principal Stars at the dates and hours given in Table 5 on pages 122 and 123.

The centre of the Map is the point overhead, or the *zenith* of the observer; while the *horizon*, containing the principal compass points, is indicated by the circular line near the circumference. The horizon of Britain (in the Maps *Hor. of Brit.*) includes the horizon for Central Europe and Canada; and the horizon of the United States (in the Maps *Hor. of U.S.*) the horizon for Southern Europe.

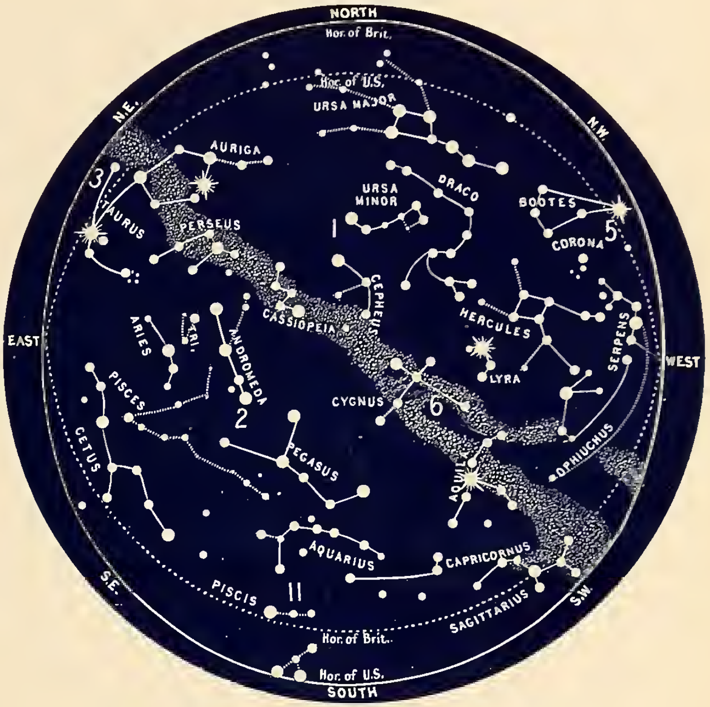
The large numbers inside the Maps are for facilitating the use of the twelve square Star Charts, each number indicating the position in the sky, of the centre of its corresponding Chart.

Maps for the Northern Hemisphere.

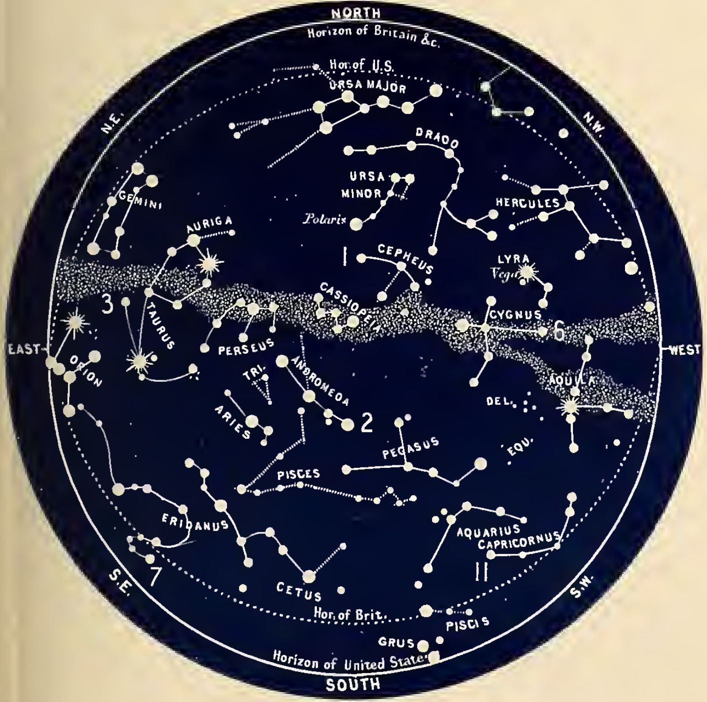
No. 9


NORTH
Hor. of Brit.
Hor. of U.S.
AURIGA
N.E.
N.W.
Pleiades
PERSEUS
URSA MAJOR
CAN. VEN.
CASSIOPEIA
URSA MINOR
COMA
ARIES
TRI.
ANDROMEDA
CEPHEUS
DRACO
BOOTES
5
1
EAST
PISCES
CORONA
SERPENS
WEST
PEGASUS
LYRA
HERCULES
CYGNUS
6
DEL.
AQUILA
OPHIUCHUS
AQUARIUS
S.E.
CAPRICORNUS
11
SAGITTARIUS
Hor. of Brit.
S.W.
Hor. of U.S.
SOUTH

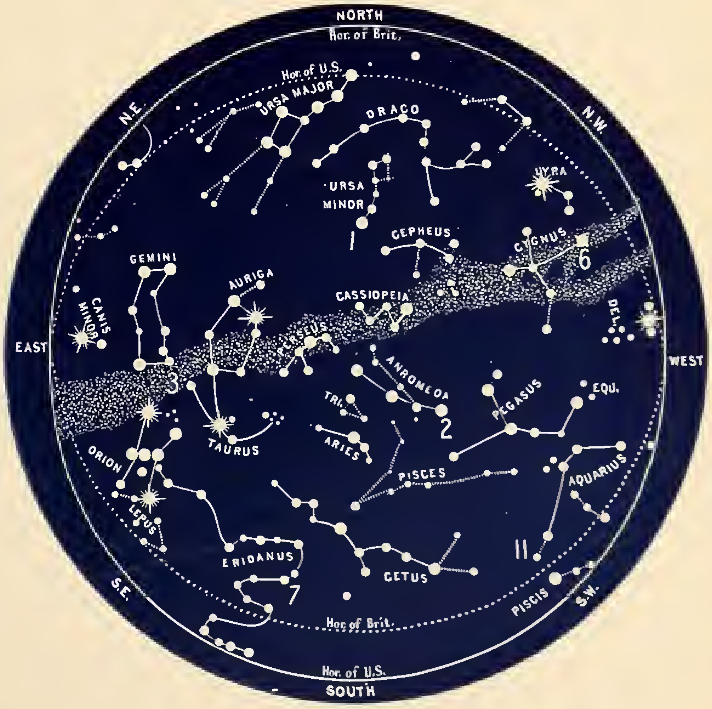
No. 10


NORTH
Hor. of Brit.
Hor. of U.S.
URSA MAJOR
N.E.
N.W.
AURIGA
3
URSA MINOR
DRACO
BOOTES
TAURUS
PERSEUS
1
CORONA
5
CEPHEUS
EAST
ARIES
TRI.
ANDROMEDA
CASSIOPEIA
HERCULES
SERPENS
WEST
LYRA
PISCES
CYGNUS
6
2
CETUS
PEGASUS
OPHIUCHUS
AQUILA
AQUARIUS
CAPRICORNUS
S.E.
PISCIS
11
SAGITTARIUS
S.W.
Hor. of Brit.
Hor. of U.S.
SOUTH

No. 11


NORTH
Horizon of Britain &c.
Hor. of U.S.
URSA MAJOR
N.E.
DRACO
N.W.
GEMINI
URSA MINOR
HERCULES
AURIGA
Polaris
1
CEPHEUS
LYRA
Vega
3
TAURUS
CASSIOPEIA
CYGNUS
6
EAST
PERSEUS
WEST
ORION
TRI.
ANDROMEDA
AQUILA
ARIES
2
DEL.
PEGASUS
EQU.
PISCES
ERIDANUS
AQUARIUS
CAPRICORNUS
S.E.
7
CETUS
11
S.W.
Hor. of Brit.
PISCIS
GRUS
Horizon of United States
SOUTH

No. 12


NORTH
Hor. of Brit.
Hor. of U.S.
URSA MAJOR
N.E.
DRACO
N.W.
URSA MINOR
LYRA
1
CEPHEUS
GEMINI
CYGNUS
6
AURIGA
CANIS MINOR
CASSIOPEIA
DEL.
EAST
PERSEUS
WEST
3
ANROMEDA
EQU.
TRI.
PEGASUS
2
ORION
TAURUS
ARIES
PISCES
AQUARIUS
LEPUS
ERIDANUS
7
CETUS
11
S.E.
S.W.
PISCIS
Hor. of Brit.
Hor. of U.S.
SOUTH

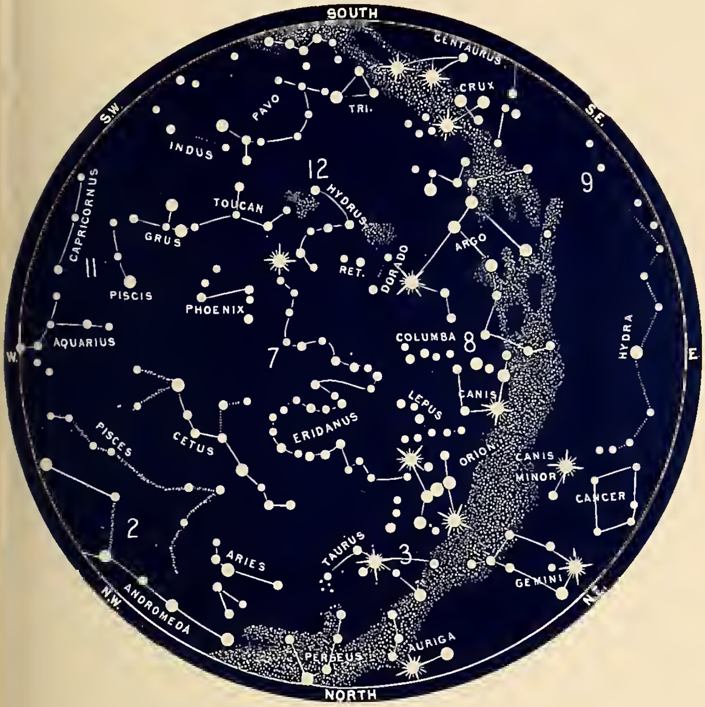
Each of the above Circular Maps is a true representation of the configurations of the principal Stars at the dates and hours given in Table 5 on pages 122 and 123.

The centre of the Map is the point overhead, or the *zenith* of the observer; while the *horizon*, containing the principal compass points, is indicated by the circular line near the circumference. The horizon of Britain (in the Maps *Hor. of Brit.*) includes the horizon for Central Europe and Canada; and the horizon of the United States (in the Maps *Hor. of U.S.*) the horizon for Southern Europe.

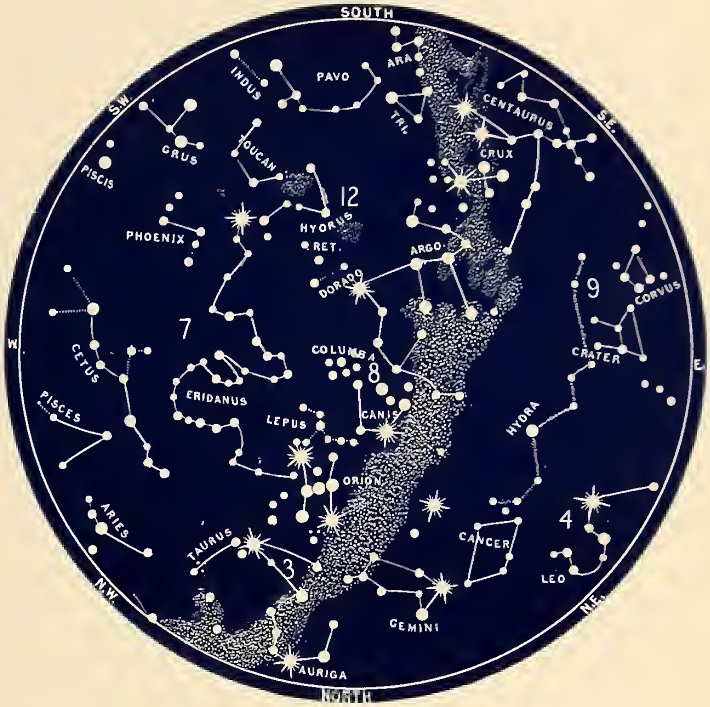
The large numbers inside the Maps are for facilitating the use of the twelve square Star Charts, each number indicating the position in the sky, of the centre of its corresponding Chart.

Maps for the Southern Hemisphere.

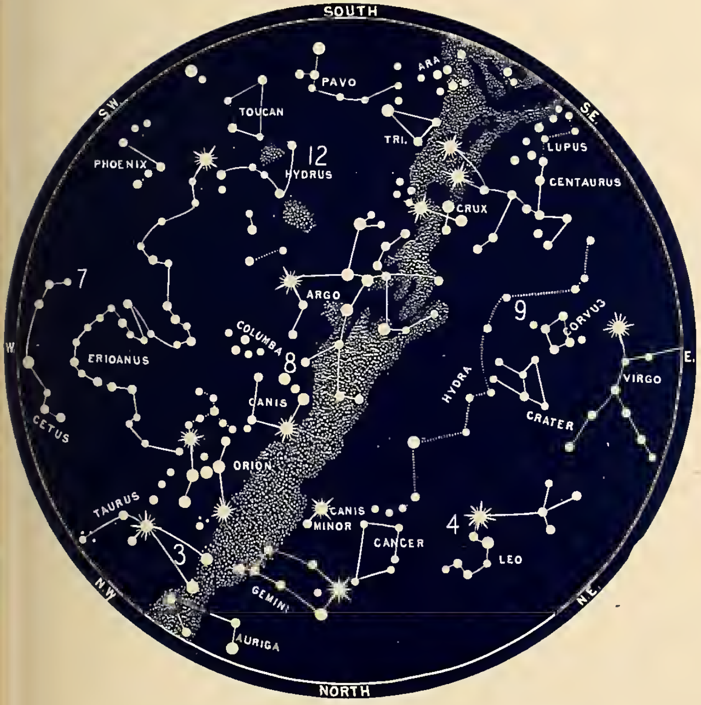
No. 13


SOUTH
CENTAURUS
CRUX
S.E.
9
PAVO
TRI.
S.W.
INDUS
12
HYDRUS
TOUCAN
CAPRICORNUS
GRUS
11
PISCIS
PHOENIX
RET.
DORADO
ARGO
AQUARIUS
W.
COLUMBA
8
7
HYDRA
E.
LEPUS
CANIS
ERIDANUS
PISCES
CETUS
ORION
CANIS MINOR
CANCER
2
ARIES
TAURUS
3
GEMINI
N.W.
ANDROMEDA
PERSEUS
AURIGA
N.E.
NORTH

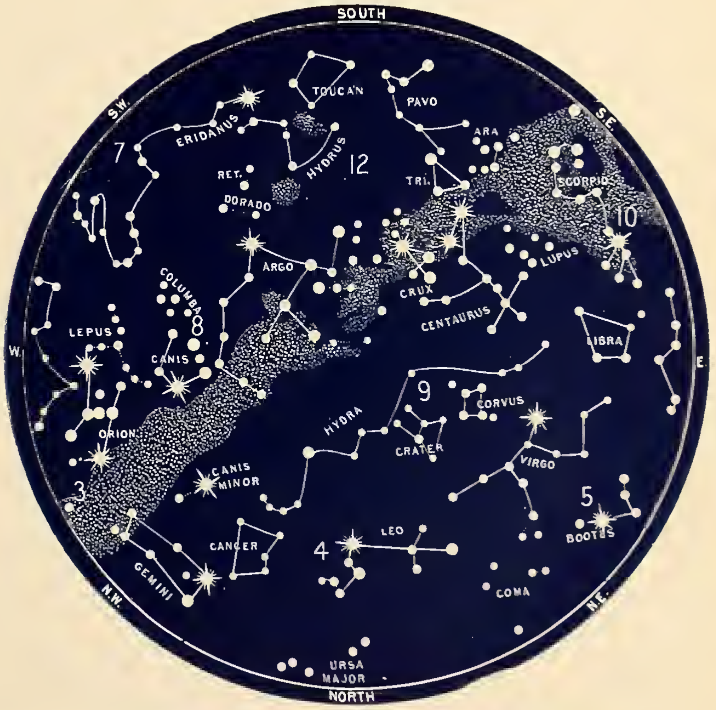
No. 14


SOUTH
ARA
PAVO
INDUS
CENTAURUS
S.W.
TRI.
S.E.
GRUS
TOUCAN
CRUX
PISCIS
12
HYDRUS
RET.
PHOENIX
ARGO
DORADO
9
CORVUS
W.
7
COLUMBA
8
CRATER
E.
CETUS
ERIDANUS
LEPUS
CANIS
HYDRA
PISCES
ORION
ARIES
4
CANCER
TAURUS
3
LEO
N.W.
GEMINI
N.E.
AURIGA
NORTH

No. 15


SOUTH
PAVO
ARA
S.W.
TOUCAN
S.E.
TRI.
LUPUS
PHOENIX
12
HYDRUS
CENTAURUS
CRUX
ARGO
7
9
CORVUS
W.
ERIDANUS
COLUMBA
8
E.
VIRGO
CANIS
HYDRA
CRATER
CETUS
ORION
TAURUS
CANIS MINOR
CANCER
4
LEO
3
N.W.
GEMINI
N.E.
AURIGA
NORTH

No. 16


SOUTH
TOUCAN
PAVO
S.W.
ERIDANUS
S.E.
7
ARA
RET.
HYDRUS
12
TRI.
SCORPIO
DORADO
10
ARGO
LUPUS
COLUMBA
CRUX
CENTAURUS
LEPUS
8
W.
LIBRA
CANIS
E.
9
CORVUS
ORION
HYDRA
CRATER
VIRGO
CANIS MINOR
3
5
CANCER
LEO
BOOTES
4
GEMINI
COMA
N.W.
N.E.
URSA MAJOR
NORTH

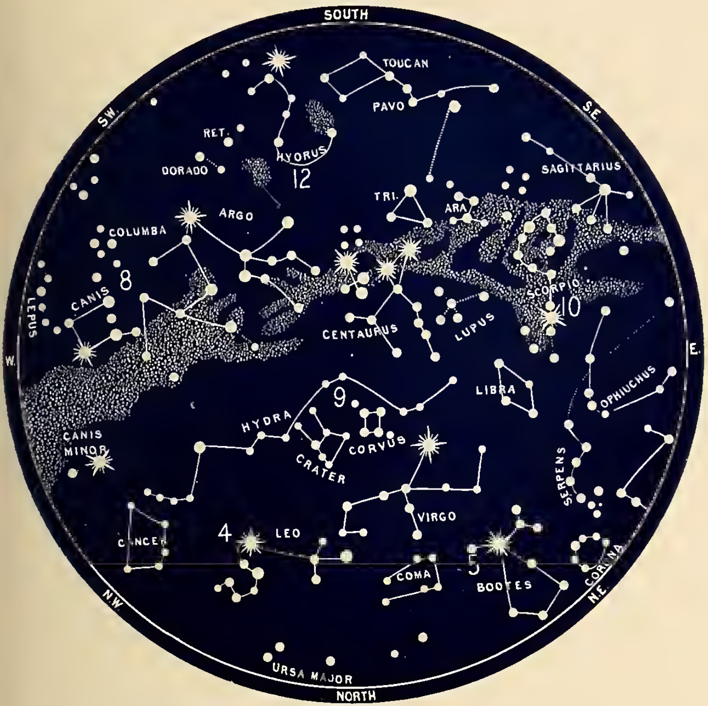
Each of the above Circular Maps is a true representation of the configurations of the principal Stars at the dates and hours given in Table 6 on pages 124 and 125.

The centre of the Map is the point overhead, or the *zenith* of the observer; while the *horizon*, containing the principal compass points, is indicated by the circular line near the circumference.

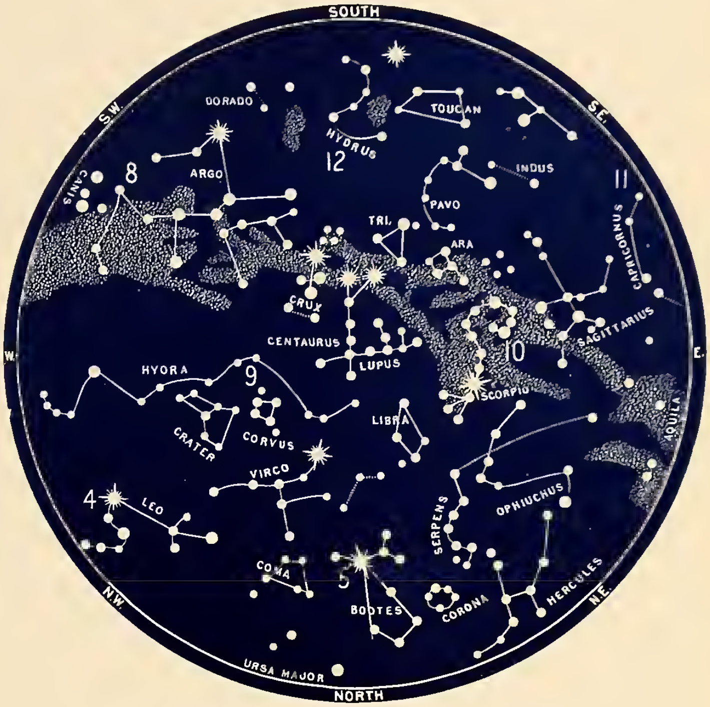
The large numbers inside the Maps are for facilitating the use of the twelve square Star Charts, each number indicating the position in the sky, of the centre of its corresponding Chart.

Maps for the Southern Hemisphere.

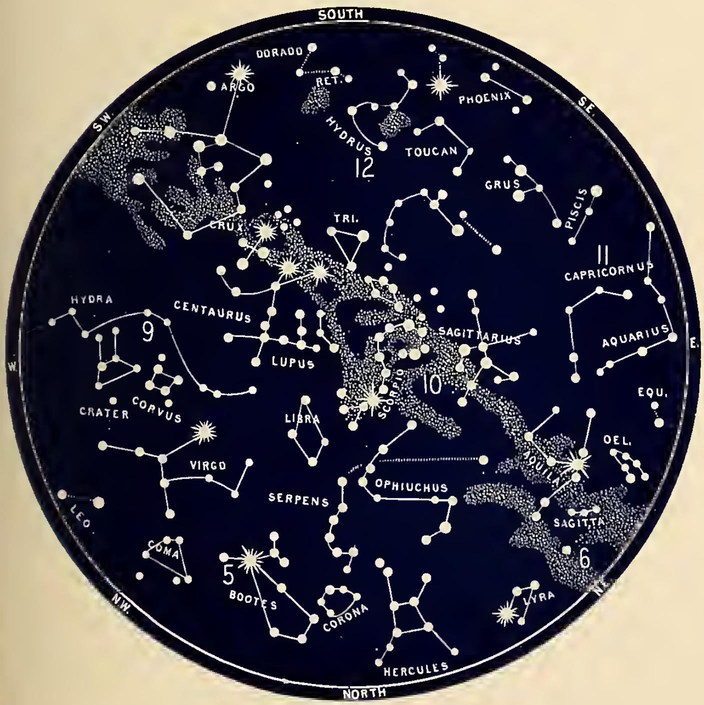
No. 17


SOUTH
TOUCAN
PAVO
SW.
SE.
RET.
HYDRUS
12
DORADO
TRI.
ARA
SAGITTARIUS
ARGO
COLUMBA
8
CANIS
LEPUS
SCORPIO
10
CENTAURUS
LUPUS
W.
E.
LIBRA
OPHIUCHUS
HYDRA
9
CORVUS
CRATER
CANIS MINOR
SERPENS
VIRGO
CANCER
4
LEO
COMA
5
BOOTES
CORONA
NW.
NE.
URSA MAJOR
NORTH

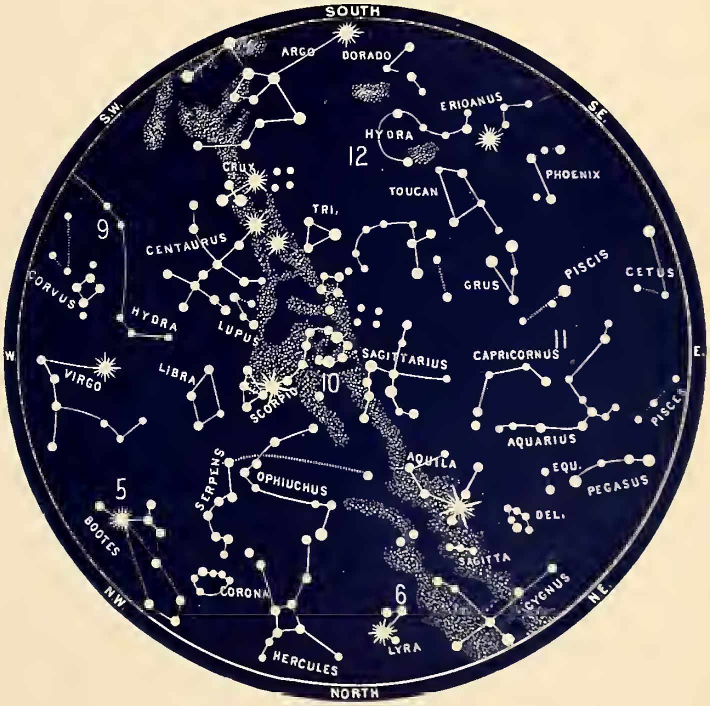
No. 18


SOUTH
DORADO
TOUCAN
SW.
SE.
HYDRUS
12
INDUS
CANIS
8
ARGO
11
PAVO
TRI.
ARA
CAPRICORNUS
CRUX
SAGITTARIUS
CENTAURUS
LUPUS
10
W.
E.
HYDRA
9
SCORPIO
LIBRA
CRATER
CORVUS
AQUILA
VIRGO
4
LEO
OPHIUCHUS
SERPENS
COMA
5
BOOTES
CORONA
HERCULES
NW.
NE.
URSA MAJOR
NORTH

No. 19


SOUTH
DORADO
ARGO
RET.
SW.
PHOENIX
SE.
HYDRUS
12
TOUCAN
GRUS
PISCIS
CRUX
TRI.
11
CAPRICORNUS
HYDRA
CENTAURUS
9
SAGITTARIUS
AQUARIUS
W.
LUPUS
E.
10
EQU.
CRATER
CORVUS
LIBRA
SCORPIO
DEL.
VIRGO
AQUILA
OPHIUCHUS
SERPENS
SAGITTA
LEO
COMA
6
5
BOOTES
CORONA
LYRA
NW.
NE.
HERCULES
NORTH

No. 20


SOUTH
ARGO
DORADO
SW.
ERIDANUS
SE.
HYDRA
12
TOUCAN
PHOENIX
CRUX
TRI.
9
CENTAURUS
PISCIS
CETUS
CORVUS
GRUS
HYDRA
LUPUS
11
CAPRICORNUS
W.
E.
SAGITTARIUS
VIRGO
LIBRA
10
SCORPIO
PISCES
AQUARIUS
AQUILA
EQU.
PEGASUS
SERPENS
OPHIUCHUS
5
DEL.
BOOTES
SAGITTA
CORONA
6
CYGNUS
NW.
NE.
LYRA
HERCULES
NORTH

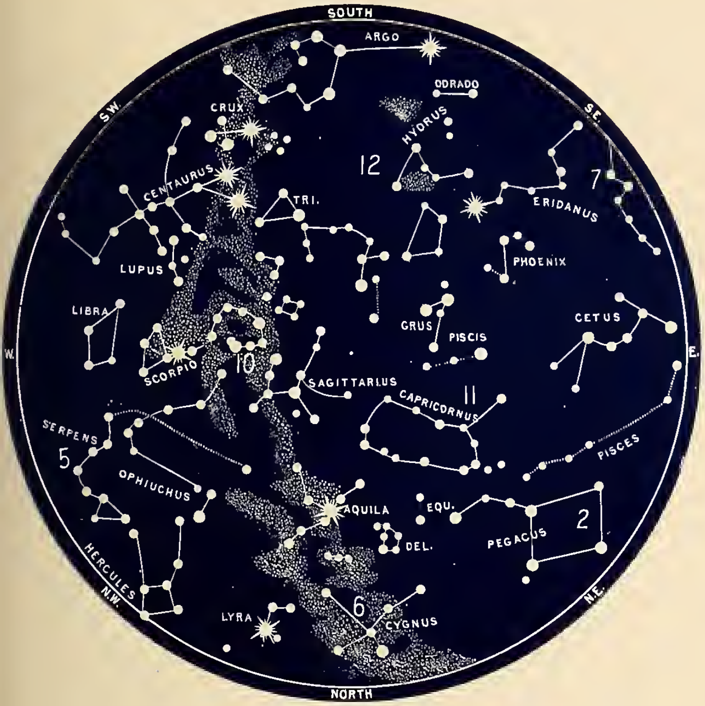
Each of the above Circular Maps is a true representation of the configurations of the principal Stars at the dates and hours given in Table 6 on pages 124 and 125.

The centre of the Map is the point overhead, or the *zenith* of the observer; while the *horizon*, containing the principal compass points, is indicated by the circular line near the circumference.

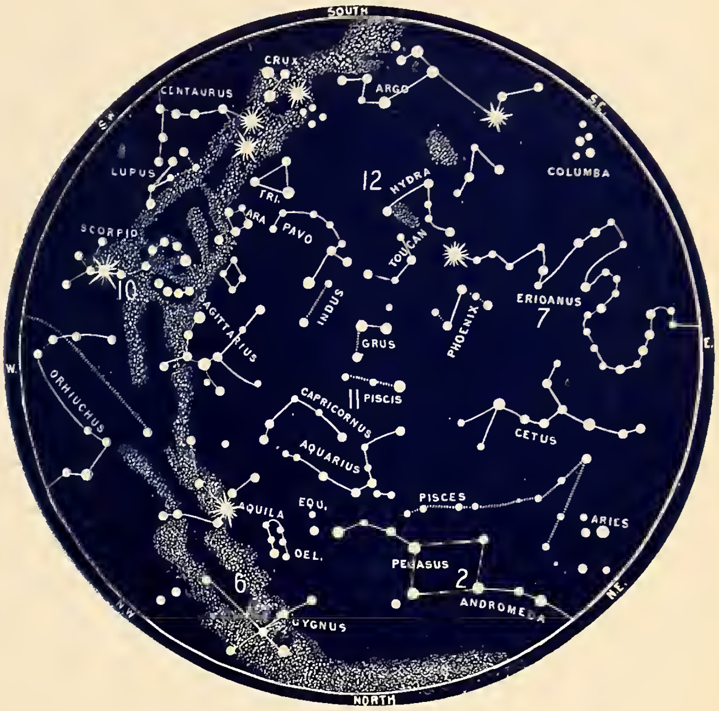
The large numbers inside the Maps are for facilitating the use of the twelve square Star Charts, each number indicating the position in the sky, of the centre of its corresponding Chart.

Maps for the Southern Hemisphere.

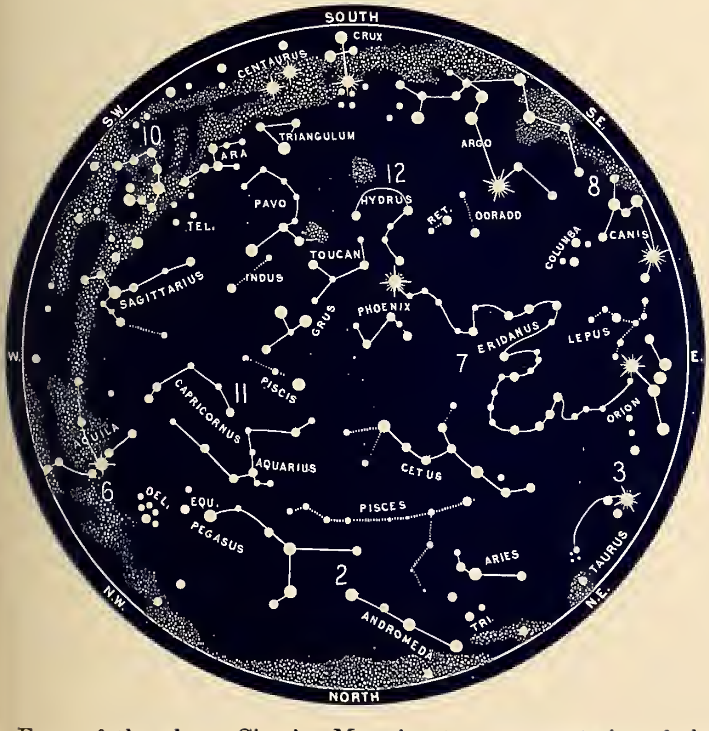
No. 21


SOUTH
ARGO
DORADO
HYDRUS
S.W.
S.E.
CRUX
12
7
CENTAURUS
TRI.
ERIDANUS
PHOENIX
LUPUS
LIBRA
W.
E.
GRUS
PISCIS
CETUS
SCORPIO
10
SAGITTARIUS
11
CAPRICORNUS
SERPENS
5
OPHIUCHUS
PISCES
AQUILA
EQU.
2
PEGASUS
DEL.
HERCULES
N.W.
N.E.
LYRA
6
CYGNUS
NORTH

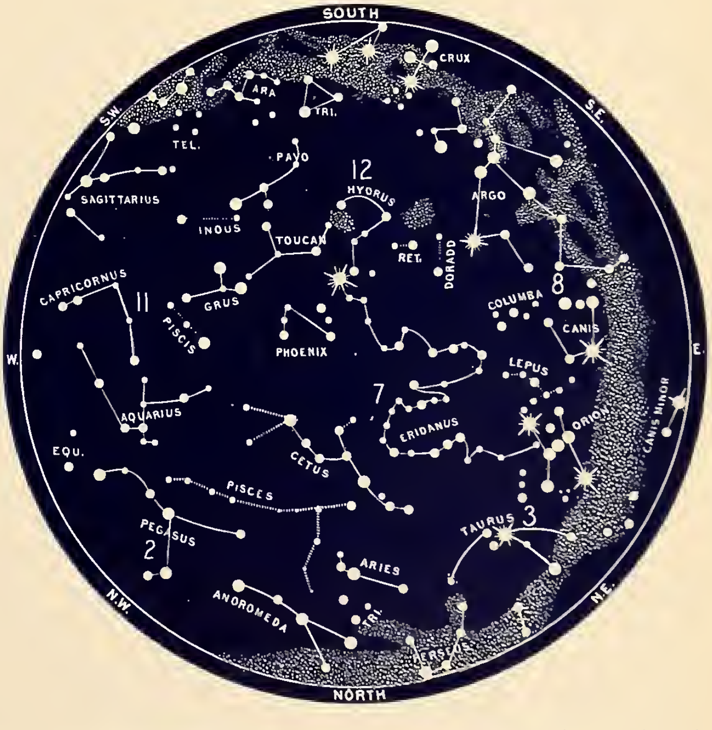
No. 22


SOUTH
CRUX
CENTAURUS
ARGO
S.W.
S.E.
LUPUS
TRI.
12
HYDRA
COLUMBA
SCORPIO
ARA
PAVO
TOUCAN
10
INDUS
SAGITTARIUS
PHOENIX
ERIDANUS
7
W.
E.
OPHIUCHUS
GRUS
11
PISCIS
CAPRICORNUS
AQUARIUS
CETUS
AQUILA
EQU.
PISCES
ARIES
DEL.
PEGASUS
6
2
ANDROMEDA
N.W.
N.E.
CYGNUS
NORTH

No. 23


SOUTH
CRUX
CENTAURUS
S.W.
S.E.
10
TRIANGULUM
ARA
ARGO
12
8
PAVO
HYDRUS
RET.
DORADO
COLUMBA
CANIS
TEL.
TOUCAN
INDUS
SAGITTARIUS
GRUS
PHOENIX
ERIDANUS
LEPUS
W.
E.
7
11
PISCIS
CAPRICORNUS
ORION
AQUILA
AQUARIUS
CETUS
6
3
DEL.
EQU.
PISCES
PEGASUS
ARIES
TAURUS
2
N.W.
N.E.
ANDROMEDA
TRI.
NORTH

No. 24


SOUTH
CRUX
ARA
TRI.
S.W.
S.E.
TEL.
PAVO
12
HYDRUS
SAGITTARIUS
ARGO
INDUS
TOUCAN
RET.
DORADO
8
CAPRICORNUS
11
GRUS
PISCIS
COLUMBA
CANIS
PHOENIX
W.
E.
LEPUS
CANIS MINOR
7
AQUARIUS
ERIDANUS
ORION
EQU.
CETUS
PISCES
TAURUS
3
PEGASUS
2
ARIES
N.W.
N.E.
ANDROMEDA
TRI.
NORTH

Each of the above Circular Maps is a true representation of the configurations of the principal Stars at the dates and hours given in Table 6 on pages 124 and 125.

The centre of the Map is the point overhead, or the *zenith* of the observer; while the *horizon*, containing the principal compass points, is indicated by the circular line near the circumference.

The large numbers inside the Maps are for facilitating the use of the twelve square Star Charts, each number indicating the position in the sky, of the centre of its corresponding Chart.

INTERESTING OBJECTS FOR THE TELESCOPE.

CHART 1.

INTERESTING OBJECTS FOR THE TELESCOPE.

CAMELOPARDALIS.

DOUBLE STARS.

52	6th and 7th magnitudes ; distance only 0″·5—a difficult object even for large telescopes.
2 (*Hev.*)	Magnitudes 5 and 9 ; distance 2″·5.
4 (*Hev.*)	Magnitudes 5 and 9 ; distance 15″.
1	Magnitudes 6 and 6 ; distance 10″. An interesting object.
2	This 6th magnitude yellowish star has a bluish 7th magnitude companion, distant 2″.
7	A 5th magnitude star with two faint companions, distant 25″ and 1″.
19 (*Hev.*)	A 5th magnitude star with faint companion, distant 20″.
32 (*Hev.*)	Magnitudes 5·5 and 6·5 ; distance 22″.

NEBULÆ AND STAR CLUSTERS.

940	A fairly large and conspicuous cluster, with slight condensation towards the centre.
1541	Large and elongated nebula, with increase of brilliancy at centre.
1691	Bright and large nebula, with slight condensation near centre.

CASSIOPEIA.

DOUBLE STARS.

σ	This greenish coloured 5th magnitude star has a deep blue 7th magnitude companion, distant 3″.
α	A reddish star, with a 9th magnitude companion distant 60″.
η	A binary star discovered by Herschel ; magnitudes 4 and 7 ; distance 6″ ; period 222 years.
ψ	This 4th magnitude star appears in a small telescope to have only a single companion, at a distance of 30″. The companion, however, is itself double ; distance 3″.
ι	Also a triple star. Magnitudes 4, 7, and 9 ; distances 1″·5 and 8″.
λ	A very close double star ; distance only 0″·5.
48	Magnitudes 5 and 8, distance 1″.

NEBULÆ AND STAR CLUSTERS.

M. 52	An irregular star cluster.
382	A cluster well seen with a very small telescope.
M. 103	Star cluster ; a most beautiful object.
63	A coarse and widely scattered cluster of nearly circular shape, with a diameter of about 20′.
120	A very fine cluster, shaped somewhat like the letter W.
256	Large and rich cluster, of 7 to 10 magnitude stars.
392	A rich cluster, 15′ in diameter ; a beautiful object.
5031	A large faint cluster of minute stars, discovered by Miss Herschel.

VARIABLE STARS.

α	Discovered by Birt in 1831 to be variable from 2·2 to 2·8 magnitude, in an irregular period.
R	This deep red-coloured star was discovered by Pogson, in 1853, to be variable in a period of about 426 days. Maximum magnitude, 4·8 to 6·8 ; minimum 12.
T	A red star, whose variability was discovered by Kürgur in 1870. Maximum magnitude, 6·5 to 7 ; minimum 11 ; period 436 days.
S	Discovered by Argelander to be variable in 1861. Maximum magnitude, 6·7 to 8 ; minimum 13 ; period 615 days.

ξ, π, 40, and 55, are suspected of variability.

CEPHEUS.

DOUBLE STARS.

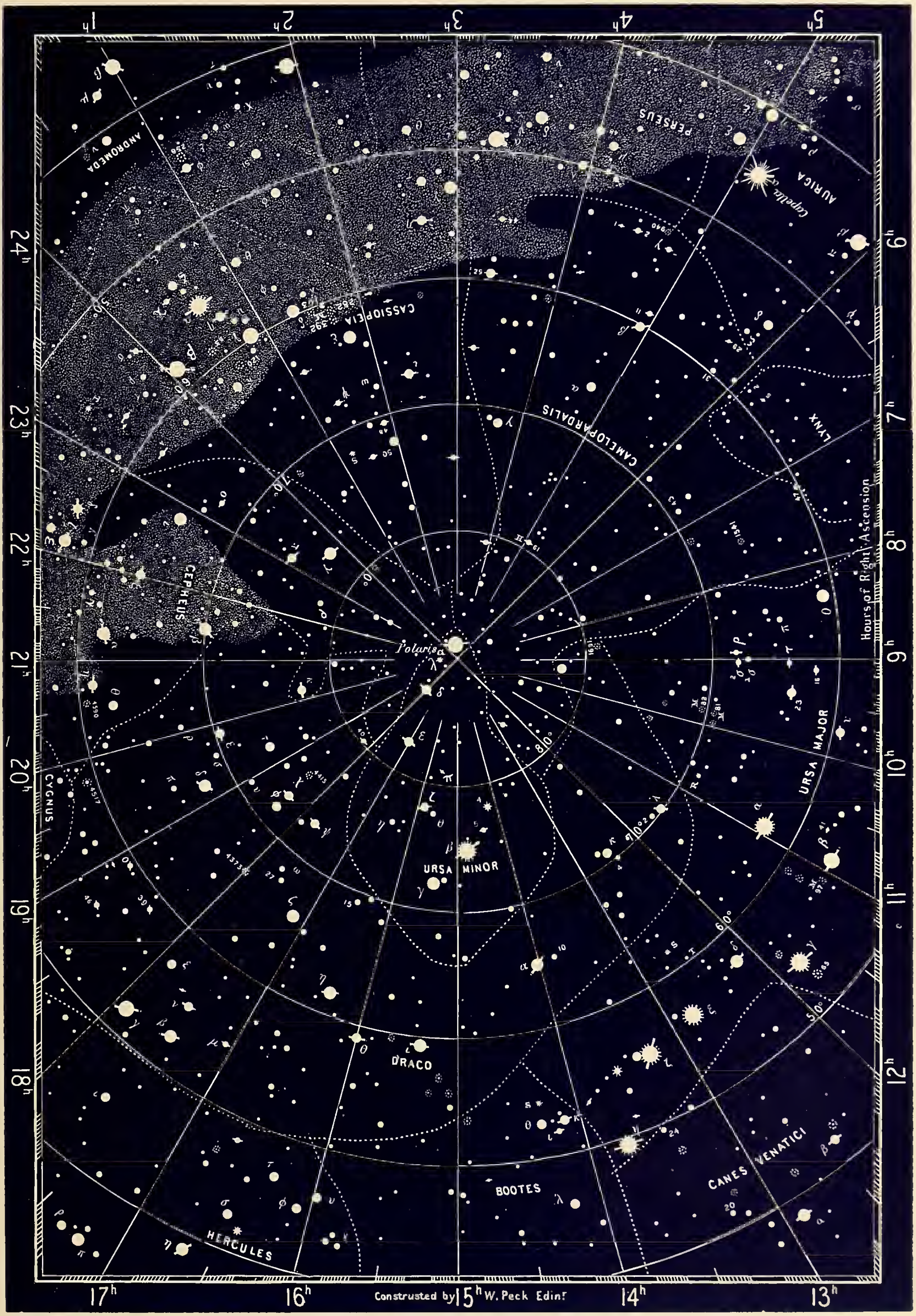
κ	Magnitudes 4, 5, and 8 ; distance 7″; colours, pale yellow and blue.
β	Magnitudes 3 and 8 ; distance 14″.
15	A sixth magnitude multiple star.
ξ	A yellowish 4·5 magnitude star, with a 7th magnitude blue companion, distant 5″.
δ	A very fine double star ; colours, yellow and blue ; distance 40″.
π	A binary star. Discovered at Pulkowa to be triple ; magnitudes, 5, 9, and 11.
ο	A binary star. Magnitudes 5·5 and 8 ; distance 27″ ; colours—bright yellow and blue.

STAR CLUSTER.

4590	A very rich cluster, discovered by Herschel.

(Description of Chart 1 continued over the next page.)

CHART 1.


1h
2h
3h
4h
5h
6h
7h
8h
9h
10h
11h
12h
13h
14h
15h
16h
17h
18h
19h
20h
21h
22h
23h
24h
ANDROMEDA
PERSEUS
AURIGA
Capella
CASSIOPEIA
CAMELOPARDALIS
LYNX
CEPHEUS
Polaris
URSA MINOR
URSA MAJOR
CYGNUS
DRACO
BOOTES
CANES VENATICI
HERCULES
Hours of Right Ascension
50°
60°
70°
80°
Construsted by W. Peck Edinr

CEPHEUS—*continued.*

VARIABLE STARS.

R	Discovered by Pogson, in 1856, to be variable from magnitudes 5 to 10, in an irregular period.
μ	Variable from magnitudes 4 to 5 ; discovered by Hind in 1848.
δ	A very regular variable star; period 5·4 days ; maximum 3·7 ; minimum 4·9.
o	Suspected of variability.

DRACO.

DOUBLE STARS.

η	A 3rd magnitude star, with a faint companion, distant about 5″.
16 and 17	These stars appear to the unaided eye as a single object. When viewed with a small telescope, however, three stars are seen ; distances 90″ and 4″.
μ	Magnitudes 4·5 and 5 ; distance 3″. Thought to be a binary star.
ν	Magnitudes 5 and 5 ; distance 62″ ; colour, pale grey.
ψ	Noticed by Flamsteed to be double ; magnitudes 4·5 and 5 ; distance 30″.
40 and 41	These yellow-coloured stars, of the 5th and 6th magnitude respectively, are distant from each other 20″.
39	A 5th magnitude triple star ; distances 3″ and 89″ ; colours—white, light blue, and red.
46	A 5th magnitude star, with a companion, distant 147″.
47	A 4th magnitude star, with a companion, distant 30″.
o	Magnitudes 4·5 and 7 ; distance 30″.
ε	Magnitudes 4 and 7 ; distance 3″. Thought to be a binary star.

NEBULÆ AND STAR CLUSTERS.

4373	A planetary nebula, with a diameter of over 30″. Can be well seen with a telescope of four inches aperture.
4415	A fairly large and brilliant nebula, whose light has been suspected to be variable.
4517	A large but not very dense cluster of 7th magnitude and fainter stars.

VARIABLE STARS.

φ and μ are thought to be variable.

URSA MAJOR.

(The remaining part of this Constellation is given on Chart 4.)

DOUBLE STARS.

σ^2	A 5th magnitude star, with an 8th magnitude companion, distant 3″.
τ	A wide double star ; distance 55″.
16	Also a wide double star ; distance 59″.
23	Magnitudes 4 and 9 ; distance 23″.
υ	A 4th magnitude star, with companion, distant 11″.
41	Magnitudes 6 and 8 ; distance 82″.
α	This bright star has an 8th magnitude companion, distant 380″.
65	Triple star ; magnitudes 6·4, 7, and 8 ; distances 64″ and 4″.
ζ	One of the finest objects in the heavens, when viewed with a small telescope.

NEBULÆ.

M. 81 & M. 82	Two fairly bright nebulæ, about half a degree apart.
M. 97	A large and faint planetary nebula, much larger than the apparent size of Jupiter.

VARIABLE STARS.

R	A remarkable variable star, discovered by Pogson in 1853. The brilliancy at maximum varies from magnitudes 6 to 8 ; but at minimum it is only about 12. These variations are performed in a period of about 303½ days.
T	The magnitude of this star is also subject to a great range of variation. The maximum is very irregular, varying from 6·5 to 8 ; the minimum is often as low as the 13th magnitude.
β	Suspected of variability with a period of 35 days.

α, ψ, γ, δ, ε, ζ, and η, are also thought to be slightly variable.

URSA MINOR.

DOUBLE STARS.

α	(*Polaris*) Magnitudes 2 and 9 ; distance 19″. The light of the bright star is yellowish, the faint companion being of a bluish colour.
5	Magnitudes 5 and 8 ; distance 56″.
β	A 2nd magnitude star with a companion, distant 200″.
ε	A star of the 4th magnitude, with companion, distant 78″.
π	A yellowish 6th magnitude star, with a 7th magnitude companion of the same colour, distant 30″.

VARIABLE STARS.

β	Thought by Struve to be subject to a slight variation of magnitude in a long period.
4	Thought to be variable.

CHART 2.

INTERESTING OBJECTS FOR THE TELESCOPE.

ANDROMEDA.

DOUBLE STARS.

μ	Magnitudes 4 and 11 ; distance 49″. A difficult object.
γ	One of the finest objects in the heavens. The large star is of a golden colour, and the 6th magnitude companion is blue. The distance between these stars is 10″. In 1842 the small star was discovered by Struve to be double ; distance less than 1″.
π	Magnitudes 4 and 9 ; distance 36″.
36	A binary star. Magnitudes 5·5 and 7 ; distance 1″·5 ; period 349 years.
59	A 6th magnitude star, with a 7th magnitude companion at a distance of 16″.

NEBULÆ AND STAR CLUSTERS.

M. 31	The Great Nebula, sometimes called the Queen of Nebulæ. A most interesting object, even for small telescopes, and easily seen with the unaided eye on a moonless night. With large instruments, long, dark gaps can be seen, and also hundreds of small stars.
M. 32	A faint star cluster, in same low power field as large nebula.
457	A cluster of coarsely scattered stars, about one and a-half degrees in diameter.
527	Nebula 15′ long by 3′ broad ; discovered by Miss Herschel.

VARIABLE STARS.

R	A long-period variable star of a rich orange colour ; discovered by Argelander in 1858. Maximum magnitude, 5·6 to 8·6 ; minimum 13 ; period 405 days.

ι, 28, 36, ξ, and 49 thought to be slightly variable.

ARIES.

DOUBLE STARS.

γ	A very fine object for small telescopes. It is probably the first double star that was discovered. The components are nearly equal in magnitude, and are separated from each other by 9″.
λ	Magnitudes 5 and 8 ; distance 37″. Also a good object for small instruments.
10	A close binary star of the 6th magnitude. The companion is of the 8th magnitude, at the distance of 1″·5.
14	A triple star. Magnitudes 6, 9, and 10 ; distances 83″ and 106″.
30	A beautiful double star. Magnitudes 6 and 6·5 ; distance 39″.
33	A 6th magnitude star, with a 9th magnitude companion, distant 29″.
π	A triple star. Magnitudes 5, 8, and 11 ; distances 3″ and 25″.
41	A 4th magnitude star, with a faint companion at a distance of 20″.
ε	A close double star. Magnitudes 5 and 6 ; distance only 1″·5.
52	A quadruple star of the 6th magnitude, but seen only with a powerful telescope.

VARIABLE STARS.

3, 7, 19, and ε	Thought to be variable.

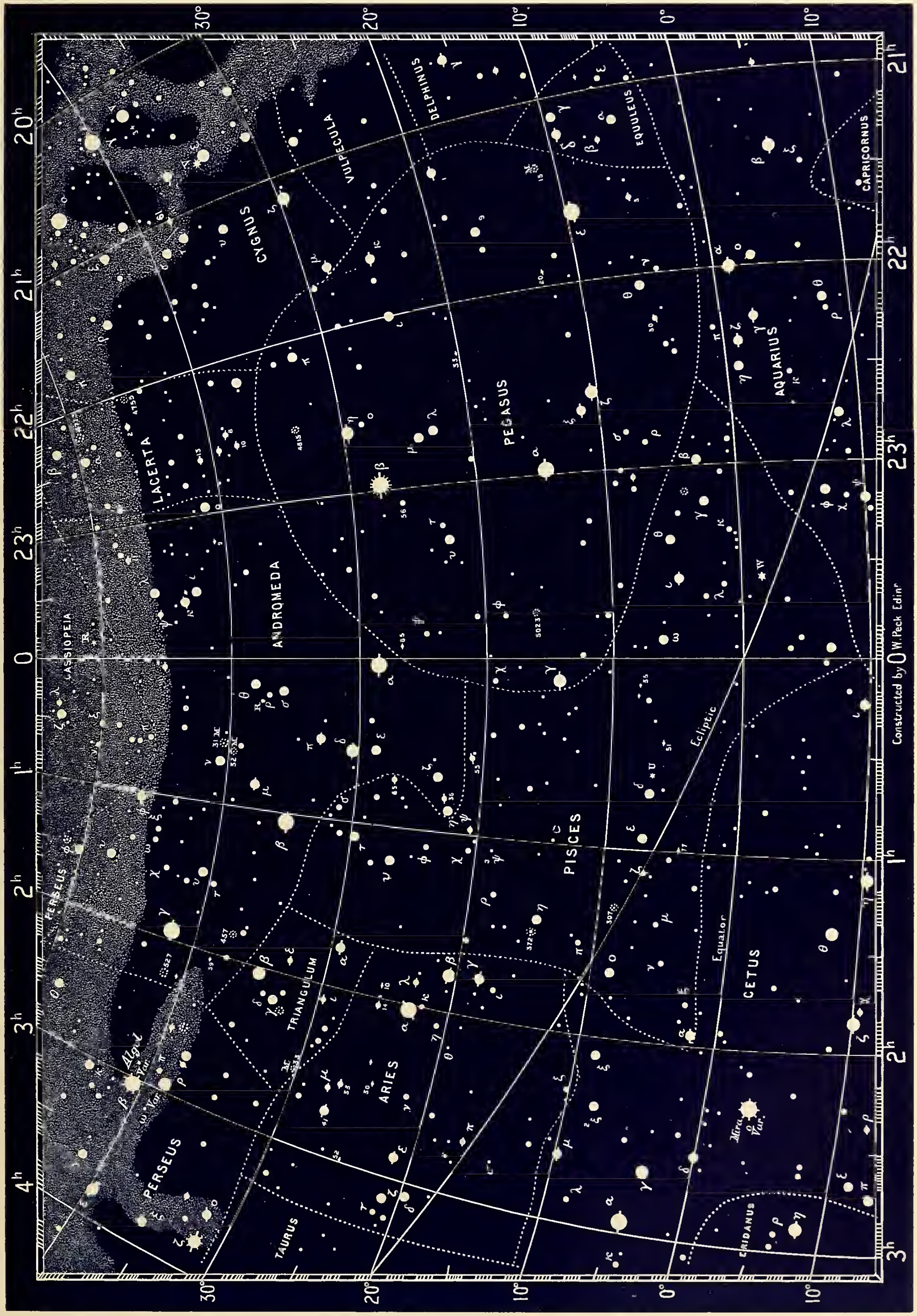
PEGASUS.

DOUBLE STARS.

1	A 4th magnitude star, with a 9th magnitude companion, distant 36″.
3	A 6th magnitude star, with a 7·5 magnitude companion at a distance of 39″.
ε	This 2nd magnitude star has two companions ; magnitudes 8 and 13 ; distances 85″ and 138″.
κ	Magnitudes 4 and 11 ; distance 11″. The primary is itself a very close double star.
20	Magnitudes 6 and 13 ; distance 51″. An exceedingly difficult object.
30	A 5th magnitude star, with a faint companion, distant 6″.
33	A triple star. Magnitudes 6, 7·5, and 9 ; distances 2″·5 and 64″.

(Description of Chart 2 continued over the next page.)

CHART 2.



CYGNUS
VULPECULA
DELPHINUS
EQUULEUS
CAPRICORNUS
LACERTA
PEGASUS
AQUARIUS
CASSIOPEIA
ANDROMEDA
PISCES
PERSEUS
TRIANGULUM
ARIES
CETUS
TAURUS
ERIDANUS
Ecliptic
Equator
Algol Var.
Mira Var.
Constructed by W. Peck Edinr
20h
21h
22h
23h
0
1h
2h
3h
4h
30°
20°
10°
0°
10°

SIDE NEAREST THE NORTHERN HORIZON IN THE SOUTHERN HEMISPHERE.

SIDE NEAREST THE SOUTHERN HORIZON IN THE NORTHERN HEMISPHERE.

PEGASUS—*continued.*

DOUBLE STARS—continued.

η	A 3rd magnitude star, with 11th magnitude companion, distant 90″.
ξ	Magnitudes 4 and 11 ; distance 12″.
β	A 2nd magnitude star, with faint companion, distant 98″.
85	Magnitudes 6 and 9 ; distance 15″. The large star is itself double, but can only be seen with large instruments. It is probably a binary star, with a period of not more than thirty years.
γ	A red-coloured 2nd magnitude star, with two faint companions.

NEBULÆ AND STAR CLUSTERS.

M. 15	A globular cluster of minute stars, visible to the naked eye. It has a diameter of about 4′, and was discovered by Maraldi in 1745.
4815	A fairly large and bright nebula, with central condensation.
5023	A scattered cluster of 10th magnitude and fainter stars.

VARIABLE STARS.

β	An irregular variable star, discovered by Schmidt in 1847. Maximum 2·2 ; minimum 2·7.
γ	Slightly variable, in a period of about 27 days.

ε, ι, θ, π, ο, 61, and 80 are thought to be slightly variable.

PISCES.

DOUBLE STARS.

35	A 6th magnitude star, with a 7·5 magnitude companion, distant 12″.
51	A 5th magnitude star, with a 9th magnitude companion, at a distance of 28″.
55	A beautiful coloured double star, magnitudes 5 and 8 ; distance 6″; colours, yellow and deep blue.
65	A double star, whose components are nearly equal in magnitude ; distance 4″.
ψ	Also equal in magnitude, distance 30″. Easily seen with small telescopes.
77	A good object for a small instrument. Magnitudes 6 and 7 ; distance 33″.
ζ	Magnitudes 5 and 7 ; distance 23″.
α	A very beautiful double star, and easily seen by aid of a small telescope. Colours, pale green and blue magnitudes 3 and 4 ; distance 3″. Thought to be a binary star.

NEBULA AND STAR CLUSTER.

307	A round nebula, with bright centre.
372	A faint globular cluster, somewhat spiral in form when viewed with large instruments.

LACERTA.

DOUBLE STARS.

2	A 5th magnitude star, with a companion, distant 15″.
8	A quadruple star. Magnitudes 6, 6·5, 8·5, and 10 ; distances 22″, 28″, 67″, and 82″.
10	A 5th magnitude star, with a faint companion, distant 59″.
13	A 5th magnitude star, with a faint companion, distant 15″.

STAR CLUSTERS.

4755	A fairly large and rich cluster of stars, from 8th to 10th magnitudes.
4773	A coarsely-scattered cluster of about 16′ in diameter.

TRIANGULUM.

DOUBLE STARS.

α	A 4th magnitude star, with a companion, distant 110″.
ε	A 5th magnitude star, with an exceedingly faint companion, distant 4″.
ι	Magnitudes 5 and 7 ; distance 4″ ; colours, yellow and blue.

STAR CLUSTER.

M. 33	A large, though faint, spiral cluster of stars, discovered by Messier. In a small telescope it appears somewhat like a nebula.

CHART 3.

INTERESTING OBJECTS FOR THE TELESCOPE.

AURIGA.

DOUBLE STARS.

4 (ω)	A 5·5 magnitude star of a greenish colour, with a 7th magnitude companion, distant 6″.
α	*Capella.* A 1st magnitude star, with several faint companions.
14	A triple star. Magnitudes 5·5, 7, and 11; distances 15″ and 13″.
26	Also a triple star. Magnitudes 6, 8, and 11; distances 12″ and 26″.
θ	A quadruple star. Magnitudes 3, 7, 9, and 10; distances 2″, 45″, and 125″.
41	A 6th magnitude star, with 6·5 magnitude companion, distant 8″.
56	Magnitudes 6 and 8; distance 37″.
λ	A 5th magnitude star, with faint companion, distant 104″.

STAR CLUSTERS AND NEBULÆ.

996	A rich field of stars from the 7th to 12th magnitudes.
1067	A very beautiful cluster of small stars.
1101	A fairly large and rich cluster of small stars.
1114	A circular cluster of stars, from the 9th to 12th magnitudes.
M. 38	A very beautiful circular cluster of stars about 10′ in diameter.
1137	A brilliant circular nebula, about 5′ in diameter.
M. 36	A cluster of stars from the 7th to 12th magnitudes, and about 9′ in diameter. Well seen with a small telescope.
M. 37	A large cluster of small stars, with a diameter of nearly half a degree. A magnificent object.
1451	A somewhat coarse cluster of stars.

VARIABLE STARS.

R	A variable star; discovered at Bonn in 1862. Maximum magnitude, 6·5 to 7·5; minimum 13; period 465 days.
ε	Discovered by Fritsch in 1821. Maximum 3·0; minimum 4·5; period irregular.
υ	Thought to be variable from 4·3 to 5·4.
κ	Thought to be variable.

GEMINI.

DOUBLE STARS.

μ	A 3rd magnitude star of a yellow colour, with a very faint companion, distant 73″.
γ	This 2·5 magnitude star has two exceedingly faint distant companions.
ε	Magnitudes 3·5 and 8; distance 111″.
38	A 5th magnitude star, with an 8th magnitude companion; distance 6″; colours, yellow and blue.
ζ	This 4th magnitude star has two companions. Magnitudes 7 and 10; distances 90″ and 65.″
λ	Magnitudes 4 and 10; distance 10″.
δ	A yellowish 3·5 magnitude star, with a reddish 8th magnitude companion at a distance of 7″.
α	*Castor.* One of the finest double stars in the heavens, and easily seen with a small telescope. Magnitudes 2·7 and 3·7; distance 5″·5. A binary star, with a period of about 1000 years.
β	*Pollux.* This brilliant star has no less than five very faint companions.
κ	Magnitudes 4 and 9; distance 6″.
ν	A 4th magnitude star, with an 8th magnitude companion, distant 112″.

STAR CLUSTERS.

1325	A coarsely-scattered cluster of 7th to 11th magnitude stars, about 7′ in diameter.
M. 35	A most striking object. The cluster is about 20′ in diameter, and contains many brilliant stars. Beautifully seen with a small instrument.
1467	A triangular cluster of small stars.
1490	A coarsely-scattered cluster of very small stars.
1549	A mass of very small stars, about 6′ in diameter.

VARIABLE STARS.

η	Discovered by Schmidt in 1865. Maximum 3·2; minimum 3·7 to 4·2; period about 229 days.
ζ	Discovered by Schmidt in 1844 to be variable from magnitude 3·7 to 4·5 in a period of 10·2 days.
R	An irregular variable star of a deep red colour. Discovered by Hind in 1848. Maximum 6·5; minimum 12.

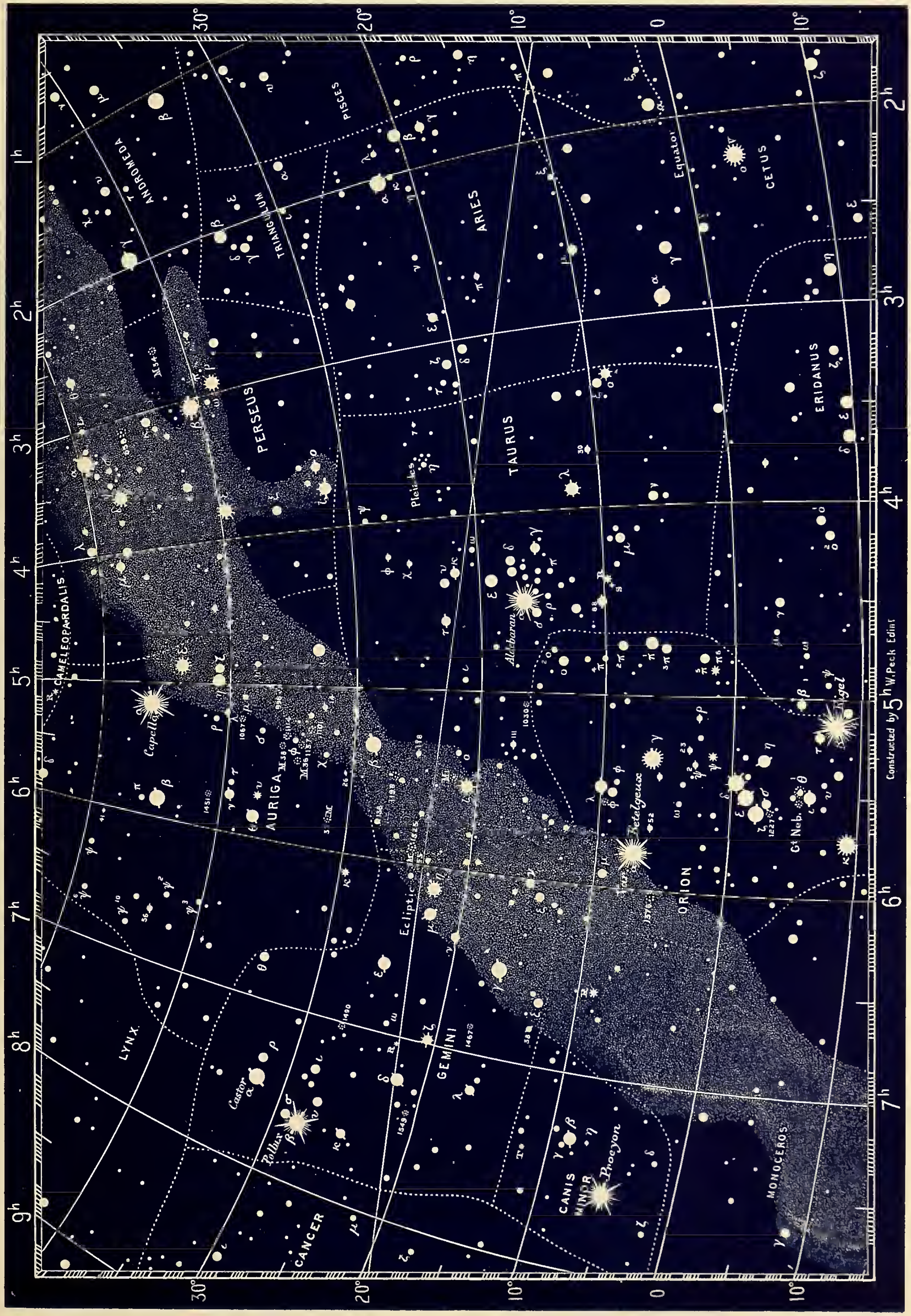
ORION.

DOUBLE STARS.

14	A very close double star. Magnitudes 6 and 7, distance about 1″.
ρ	Magnitudes 5 and 9; distance 7″; colours, yellow and bluish white.
β	*Rigel.* This brilliant star has an 8th magnitude companion, distant 10″. Well seen with a telescope of 4 inches aperture. In large instruments the companion has been seen to be double.
η	A triple star. Magnitudes 3, 5, and 5; distances 1″ and 110″.
ψ^2	This 5th magnitude star has a very faint companion; distance 3″.
δ	A 2nd magnitude star, with a 7th magnitude companion, distant 53″.

(Description of Chart 3 continued over the next page.)

CHART 3.


ANDROMEDA
PISCES
TRIANGULUM
ARIES
CETUS
Equator
PERSEUS
TAURUS
ERIDANUS
Pleiades
Aldebaran
CAMELEOPARDALIS
Capella
AURIGA
ORION
Rigel
Betelgeux
Gt Neb.
GEMINI
Ecliptic
LYNX
Castor
Pollux
CANCER
CANIS MINOR
Procyon
MONOCEROS
1h
2h
3h
4h
5h
6h
7h
8h
9h
30°
20°
10°
0
10°
Constructed by W. Peck Edinr

Side nearest the Northern Horizon in the Southern Hemisphere.

Side nearest the Southern Horizon in the Northern Hemisphere.

DOUBLE STARS—continued.

ORION—*continued.*

λ	Magnitudes 3 and 6; distance 4″.
ι	A triple star. Magnitudes 3, 7, and 9; distances 12″ and 49″.
σ	A multiple star. Magnitudes 4, 6, 7, and 11; distances 12″, 61″, and 12″.
ζ	A very beautiful double star. Magnitudes 2 and 6; distance 3″. There is another companion of the 10th magnitude, at a distance of 53″.
52	A 5th magnitude star, with a 6th magnitude companion, distant nearly 2″.
23	Magnitudes 5 and 7; distance 32″.
θ^1	The well-known trapezium in the Great Nebula. Magnitudes 6, 7, 7·5, and 8. These four stars are well seen with a small instrument. In large telescopes six stars are seen.

NEBULÆ AND STAR CLUSTER.

M. 42	The great Nebula. One of the most wonderful objects in the heavens. Before the spectroscope was applied to it, it was supposed to be a cluster of exceedingly faint stars, but is now known to be a mass of incandescent gas.
1227	A fairly brilliant and extensive nebula, with dark space near centre.
1376	A cluster of small stars about 6′ in diameter.

VARIABLE STARS.

α	*Betelgeux.* Maximum 1·0; minimum 1·4; period irregular.
δ	Variable from 2·2 to 2·7 in an irregular period.

π^6, ψ, γ, and κ are thought to be variable.

DOUBLE STARS.

PERSEUS.

η	A 4th magnitude star, with an 8th magnitude companion, distant 28″.
o	A 5th magnitude star, with a 9th magnitude companion, distant 20″.
ζ	A quintuple 3rd magnitude star. The companions are all very faint.
ε	Magnitudes 3 and 8; distance 9″.
μ	A 4th magnitude star, with an 8th magnitude companion at a distance of 15″.
θ	A 4th magnitude triple star. Distance of principal companion 15″.
γ	This 3rd magnitude star has a faint companion, distant 6″.

STAR CLUSTERS.

M. 34	A coarsely-scattered cluster of stars, which can be beautifully seen with small telescopes.
658	A rich cluster of stars, about 8′ in diameter.
212 and 221	These two large and brilliant clusters of stars form one of the most brilliant telescopic objects in the heavens.

VARIABLE STARS.

ρ	An orange-coloured irregular variable star, discovered by Schmidt in 1854. Maximum magnitude, 3·4; minimum 4·2.
β	*Algol.* One of the most interesting variable stars. Maximum magnitude, 2·2; minimum 3·7; period 2 days 20 hours 48 minutes 54 seconds.

ε and δ are thought to be slightly variable.

DOUBLE STARS.

TAURUS.

7	A 6th magnitude star, with a 10th magnitude companion at a distance of 22″. The primary is itself double when seen with a very powerful instrument.
η	The brightest star in the Pleiades. A very beautiful 3rd magnitude quadruple star, and well seen with a small telescope.
30	Magnitudes 5 and 9; distance 9″.
φ	A 5th magnitude star, with an 8th magnitude companion, distant 56″.
χ	A 6th magnitude star, with an 8th magnitude companion, distant 19″.
κ	Magnitudes 5 and 6; distance 339″.
α	*Aldebaran.* This brilliant star has one or two very faint companions.
88	Magnitudes 5 and 8; distance 69″.
τ	An easily-divided double star. Magnitudes 4 and 7; distance 62″.
111	Magnitudes 5 and 8; distance 75″.
118	Magnitudes 6 and 7; distance 5″.
62	Magnitudes 6 and 8; distance 29″.

NEBULA AND STAR CLUSTERS.

1030	A large cluster of faint stars.
M. 1	The Crab Nebula, near the star ζ; discovered by Bevis in 1731.
1199	A large cluster of faint stars of nearly equal magnitude.

VARIABLE STARS.

λ	A variable star of the Algol type, discovered by Baxendell in 1848. Maximum magnitude, 3·4; minimum 4·2; period 3 days 22 hours 52 min.
o	Thought to be slightly variable, in a period of about 7 days.

CHART 4.

INTERESTING OBJECTS FOR THE TELESCOPE.

CANIS MINOR.

DOUBLE STARS.

α	*Procyon.* This brilliant star has several very faint companions.
14	A 5th magnitude triple star. The magnitudes of the companions are 7 and 8 ; distances 76″ and 112″.
η	A 5th magnitude star, with an exceedingly faint companion at a distance of 4″.

CANCER.

DOUBLE STARS.

ζ	A very interesting triple star. Magnitudes 5, 6, and 5·5 ; distances 1″ and 5″.
ϕ^2	Magnitudes 6 and 6·5 ; distance 5″. An interesting object for small telescopes.
υ^1	Magnitudes 6 and 7 ; distance 6″.
ι	A 4th magnitude star, with a 6th magnitude companion at a distance of 31″.
σ^2	A close double star. Magnitudes 6 and 7 ; distance less than 2″.
66	Magnitudes 6 and 8 ; distance 5″.

STAR CLUSTERS.

M. 44	The *Præsepe* of the Ancients. A very fine object for small telescopes.
M. 67	A cluster of faint stars, forming a very beautiful object.

VARIABLE STARS.

R	Discovered to be variable by Schwerd in 1829. Maximum magnitude, 6·5 ; minimum 12 ; period 354 days.

ψ and ι are thought to be variable.

LEO.

DOUBLE STARS.

6	A 6th magnitude star, with a 9th magnitude companion, distant 39″.
7	A 6th magnitude star, with an 8th magnitude companion, distant 43″.
γ	This 2nd magnitude yellowish star, has a red 3·5 magnitude companion at a distance of 3″. It is one of the finest objects in the heavens, and is a binary star, in a period of 407 years.
49	Magnitudes 6 and 9 ; distance 2·5″.
54	A 4th magnitude star, with a 7th magnitude companion of a bluish colour, at a distance of 6″.
ι	Magnitudes 4 and 7 ; distance 3″ ; colours, yellow and blue.
τ	A 5th magnitude star, with a 7th magnitude companion, at a distance of 95″. Well seen with a small telescope.
90	Magnitudes 6, 7, and 9 ; distances 4″ and 64″.
93	A 4th magnitude star, with an 8th magnitude companion, at a distance of 74″.
ζ	A 3rd magnitude star, with a 7th magnitude companion, at a distance of 314″.

NEBULÆ.

2184	Large and round nebula, with condensation near centre.
2203	Two faint nebulæ, with condensation at centre.
2301	Large oval shaped nebula, with star-like nucleus.
M. 65 & M. 66	Two large, though faint, nebulæ, somewhat elongated in shape.

VARIABLE STARS.

R	Variable from 5th to 10th magnitude, in a period of 313 days.

ξ, ψ, 40, φ, and β are thought to be variable.

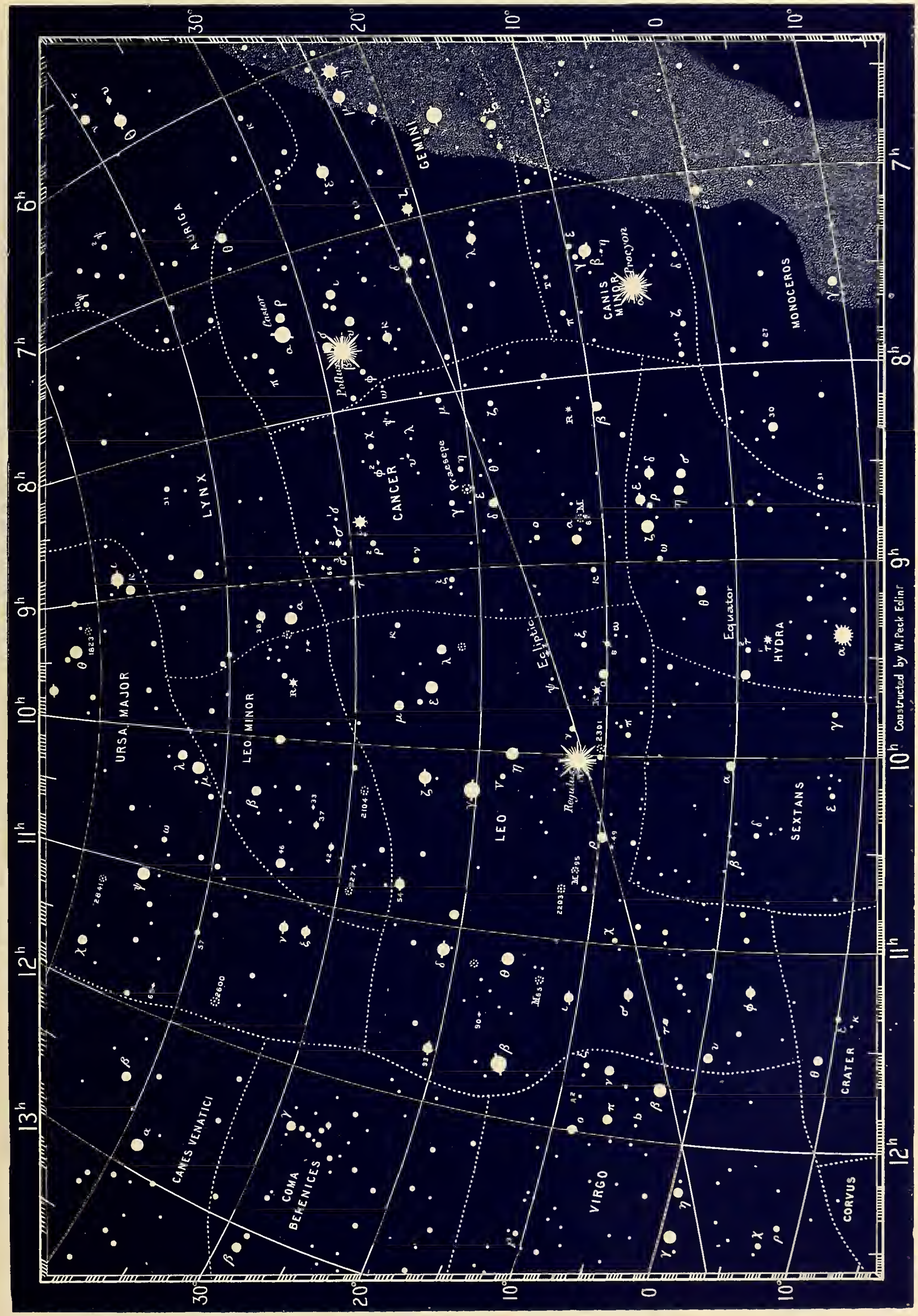
LEO MINOR.

DOUBLE STARS.

7	A 6th magnitude star, with a companion, at a distance of 55″.
33	A 6th magnitude star, with a companion, at a distance of 20″.
42	A wide 5th magnitude double star ; distance 200″.

(*Description of Chart 4 continued over the next page.*)

CHART 4.


GEMINI
AURIGA
Castor
Pollux
CANIS MINOR
Procyon
MONOCEROS
LYNX
CANCER
Praesepe
URSA MAJOR
LEO MINOR
LEO
Regulus
Ecliptic
Equator
HYDRA
SEXTANS
CRATER
CORVUS
VIRGO
COMA BERENICES
CANES VENATICI
6h
7h
8h
9h
10h
11h
12h
13h
30°
20°
10°
0
Constructed by W. Peck Edinr

Side nearest the Northern Horizon in the Southern Hemisphere.

Side nearest the Southern Horizon in the Northern Hemisphere.

LEO MINOR,—*continued.*

NEBULÆ.

2104	A fairly brilliant nebula, somewhat elliptical in shape.
2274	A large and brilliant nebula. which is thought to be a distant star cluster.

VARIABLE STARS.

R	Maximum magnitude, 6 to 7·5 ; minimum 11 ; period 375 days.

LYNX.

DOUBLE STARS.

5	A triple star ; magnitudes 6, 8, and 10 ; distances 30″ and 96″.
12	A triple star ; magnitudes 5, 6, and 7 ; distances 1·5″ and 9″.
19	Magnitudes 6 and 7 ; distance 15″.
24	A 5th magnitude double star ; distance 60″.
38	A 4th magnitude star, with a 7th magnitude companion at a distance of 3″.

URSA MAJOR.

DOUBLE STARS.

(The remaining part of this Constellation is given on Chart 1.)

ι	This 3rd magnitude star has a faint companion at a distance of 10″.
ξ	A rapid binary star ; magnitudes 4 and 5 ; distance 2″ ; period 60 years.
57	Magnitudes 5 and 8 ; distance 5″.
65	Magnitudes 6 and 8 ; distance 4″.

NEBULÆ.

1823	A fairly brilliant nebula, about 6′ in diameter.
2600	A bright nebula, with a diameter of about 4″.
2841	A large bright and oval shaped nebula.

CHART 5.

INTERESTING OBJECTS FOR THE TELESCOPE.

BOOTES.

DOUBLE STARS.

1	Magnitudes 6 and 9 ; distance 5″.
κ	This 4th magnitude greenish star has a bluish 7th magnitude companion at a distance of 13″.
ι	A 4th magnitude star, with a 7th magnitude companion at a distance of 38″.
π	Magnitudes 4 and 6 ; distance 7″.
ζ	Magnitudes 3 and 4 ; distance 1″. A difficult object, requiring a very powerful telescope to observe it.
ε	A very beautiful double star. Magnitudes 2 and 6 ; distance 3″ ; colours, yellow and blue.
ξ	A binary star. Magnitudes 4 and 6 ; distance 4″ ; period about 130 years.
39	Magnitudes 6 and 6·5 ; distance 4″.
44	Magnitudes 5 and 6 ; distance 5″; colours, yellow and blue.
μ	Magnitudes 4 and 7 ; distance 108″.

VARIABLE STARS.

R	Maximum magnitude 5·9 to 7·5 ; minimum 11 to 12 ; period about 223 days.
34	Variable from 5·2 to 6·1 in a period of about 370 days.
π and μ	Are thought to be variable.

CANES VENATICI.

DOUBLE STARS.

2	A 5th magnitude star, with an 8th magnitude companion at a distance of 11″. The colours are yellow and blue.
α	A 3rd magnitude star, with a 6th magnitude companion at a distance of 20″.
15 and 17	These two 5th magnitude stars, situated from each other 4′ 30″, form an interesting object for a very small telescope.
25	Magnitudes 5 and 7, distance 1″.

NEBULÆ AND STAR CLUSTER.

M. 94	A small bright nebula, having the appearance of a comet.
M. 51	The wonderful spiral nebula, which requires a large telescope to reveal its starry nature.
M. 3	A brilliant globular cluster of not less than 1000 small stars. Well seen with a small telescope.
M. 63	A faint oval nebula of about 10′ in length.

COMA BERENICES.

DOUBLE STARS.

2	A 6th magnitude star, with a 7·5 magnitude companion at a distance of 4″.
12	Magnitudes 5 and 8 ; distance 66″.
24	Magnitudes 5 and 6 ; distance 20″; colours, yellow and blue.
35	A triple star. Magnitudes 5, 8, and 9 ; distances 1″·5 and 29″.

NEBULÆ AND STAR CLUSTERS.

2752	A small globular cluster of stars, densely collected at centre.
2838	A faint nebula, of a spiral form.
M. 85	A somewhat faint nebula.
M. 53	A very beautiful cluster of minute stars.
M. 64	A large nebula, with very bright nucleus.

CORONA.

DOUBLE STARS.

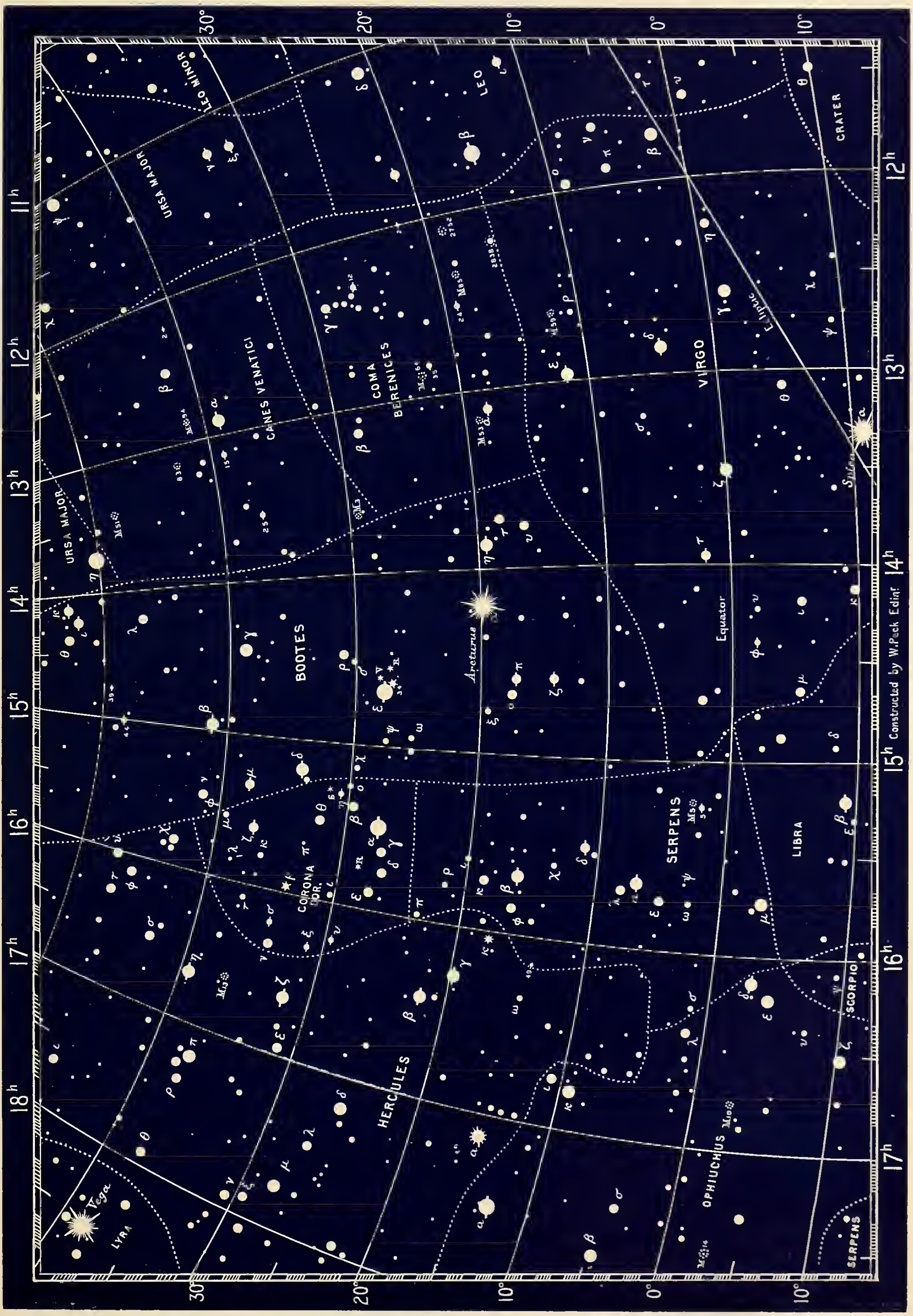
ζ	A 4th magnitude star, with a 5th magnitude companion at a distance of 6″.
σ	Magnitudes 5 and 6 ; distance 4″ ; colours, yellow and blue.
υ	A 5th magnitude star, with four faint companions.

VARIABLE STARS.

R	Variable from magnitude 5·8 to 13, in a period of about 359 days.
S	Maximum magnitude 6 to 8 ; minimum magnitude 12 to 13 ; period 361 days.
T	Variable from 2·0 to 9·3. A temporary star whose last maximum brilliancy was in May, 1866.

(Description of Chart 5 continued on next page.)

CHART 5.


URSA MAJOR
LEO MINOR
LEO
CRATER
CANES VENATICI
COMA BERENICES
VIRGO
Ecliptic
URSA MAJOR
BOOTES
Arcturus
Equator
Spica
SERPENS
LIBRA
CORONA BOR.
HERCULES
OPHIUCHUS
SCORPIO
SERPENS
LYRA
Vega
Constructed by W. Peck Edin^r
11h
12h
13h
14h
15h
16h
17h
18h
30°
20°
10°
0°
10°

SIDE NEAREST THE NORTHERN HORIZON IN THE SOUTHERN HEMISPHERE.

SIDE NEAREST THE SOUTHERN HORIZON IN THE NORTHERN HEMISPHERE.

SERPENS.

DOUBLE STARS.

5	A 5th magnitude double star ; distance 10″.
δ	A 3rd magnitude star, with a 4th magnitude companion at a distance of 3″. Thought to be a binary star.
β	Magnitudes 3 and 9 ; distance 31″.
49	Magnitudes 6 and 7 ; distance 4″.

STAR CLUSTER.

M. 5	A beautiful assemblage of very small stars, somewhat condensed near the centre.

CHART 6.

INTERESTING OBJECTS FOR THE TELESCOPE.

CYGNUS.

DOUBLE STARS.

β	A very beautiful object for small telescopes. Magnitudes 3 and 5 ; distance 34″ ; colours, orange and blue.
16	Magnitudes 6 and 6 ; distance 37″.
δ	A double star, but very difficult to observe. The companion is of the 8th magnitude, and is distant from the primary less than 2″.
17	A reddish 6th magnitude star, with a blue 8th magnitude companion at a distance of 26″.
ψ	Magnitude 6 and 7·5 ; distance 3″.
32	A triple star. Magnitudes 5, 5, and 7 ; distances 338″ and 107″.
49	Magnitudes 6 and 8 ; distance 3″.
52	A 4th magnitude star, with a 9th magnitude companion at a distance of 6″.
61	One of the first stars whose distance has been determined (*see Chapter 3*). The magnitudes are 5 and 6 ; distance 20″.
μ	Magnitudes 5 and 6 ; distance 4″. There is also another companion at a distance of 217″.

STAR CLUSTERS.

4544	A rich star cluster 15′ in diameter.
4575	A fine cluster of small stars.
M. 39	A large and brilliant cluster of stars.

VARIABLE STARS.

63	Thought to be variable from magnitude 4·7 to 6·0.
R	Variable from the 6th to the 13th magnitude, in a period of about 425 days.
χ	Discovered by Kirch in 1686. Maximum magnitude, 4 to 6 ; minimum 13 ; period about 406·5 days.
P	A 6th magnitude star, which in the year 1600 increased to the 3rd magnitude.
T	Variable from magnitude 5·5 to 6 in an irregular period.
η	Thought to be variable.

DELPHINUS.

DOUBLE STARS.

β	This 3rd magnitude star has a faint companion at a distance of 32″.
κ	A 5th magnitude double star ; distance 13″.
α	A 4th magnitude star, with a 9th magnitude companion at a distance of 35″.
γ	Magnitudes 4 and 5 ; distance 12″. Well seen with a very small telescope.

EQUULEUS.

DOUBLE STARS.

ε	A 5th magnitude star, with a 7th magnitude companion at a distance of 11″. The primary has been found to be an exceedingly close double star.
2	Magnitudes 6 and 6 ; distance 3″.
γ	A triple star. Magnitudes 5, 6, and 10 ; distances 366″ and 2″.
δ	Also a triple star. Magnitudes 5, 10, and 10 ; distances 0″·5 and 23″.

HERCULES.

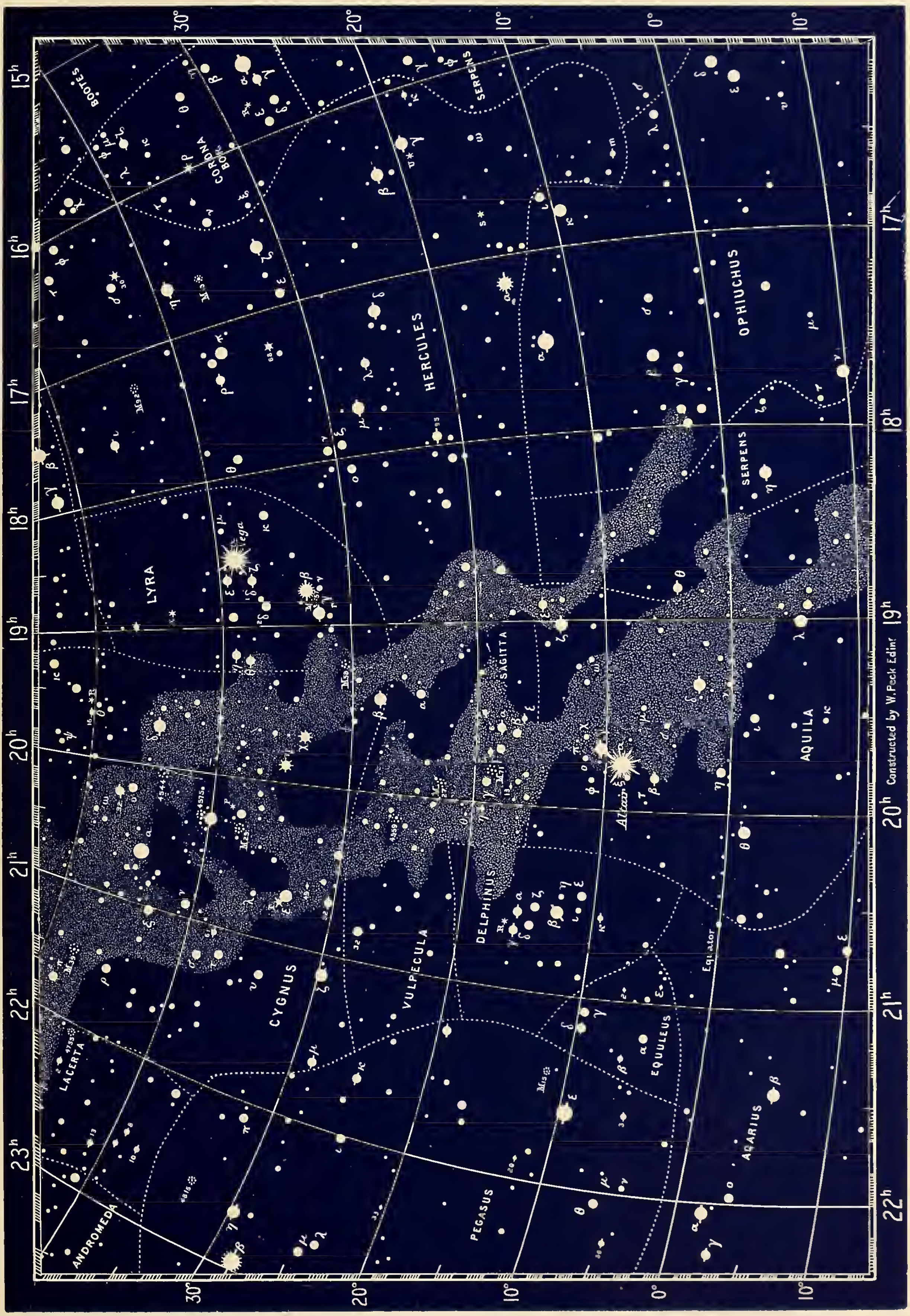
DOUBLE STARS.

κ	A 5th magnitude star, with a sixth magnitude companion at a distance of 31″.
γ	A 4th magnitude double star ; distance 39″.
m	An easily divided double star. Magnitudes 6 and 6 ; distance 69″.
ζ	A rapid binary star. Magnitudes 3 and 6 ; distance less than 2″ ; period 35 years (*see Plate of Double Stars*).
α	Magnitudes 3 and 6 ; distance 5″.
δ	Magnitudes 3 and 8 ; distance 19″.
ρ	Magnitudes 4 and 6 ; distance 4″. Thought to be a binary star.
μ	A 3rd magnitude star, with a 9th magnitude companion at a distance of 31″. The companion is an exceedingly close double star.
95	Magnitudes 5 and 5 ; distance 6″.

(Description of Chart 6 continued over the next page.)

CHART 6.

Side nearest the Northern Horizon in the Southern Hemisphere.


BOOTES
CORONA BOR.
SERPENS
HERCULES
OPHIUCHUS
LYRA
Vega
SAGITTA
AQUILA
Altair
CYGNUS
VULPECULA
DELPHINUS
EQUULEUS
AQUARIUS
PEGASUS
LACERTA
ANDROMEDA
Equator
15h
16h
17h
18h
19h
20h
21h
22h
23h
30°
20°
10°
0°
10°
Constructed by W. Peck Edinr

Side nearest the Southern Horizon in the Northern Hemisphere.

HERCULES—*continued.*

STAR CLUSTERS.

M. 31	One of the finest globular clusters in the heavens. Discovered by Halley in 1714. This magnificent object can be fairly well seen with a small telescope.
M. 92	A very fine cluster, with intensely bright centre.

VARIABLE STARS.

U	Variable from magnitude 6 to 11 in a period of 408 days.
30	An irregular variable star. Maximum magnitude 5 ; minimum 6·2.
S	Maximum magnitude, 6 to 7 ; minimum 12 ; period 303 days.
α	Variable from 3·1 to 3·9 in an irregular period.
68	Variable from 4·6 to 5·4 in a period of 38·5 days.

LYRA.

DOUBLE STARS.

α	*Vega.* This brilliant star, has several very faint companions.
ε	One of the most interesting double stars in the heavens. With a very small instrument the two stars are easily seen, being situated at a distance of 200″. In a telescope of three or four inches aperture, however, each star is seen to be double ; distances 3″ and 3″ ; magnitudes 4 and 6, and 5 and 5.
ζ	Magnitudes 4 and 5 ; distance 44″.
β	A triple star, whose magnitudes are 4, 7, and 8, at distances of 46″ and 66″.
η	A bluish 4th magnitude star, with a faint companion at a distance of 28″.

NEBULÆ.

M. 57	The only ring nebula that can be seen with a small telescope.
M. 56	A faint resolvable nebula of about 5′ in diameter.

VARIABLE STARS.

R	Variable from 4·3 to 4·6 in a period of 46 days.
β	Variable from 3·4 to 4·5 in about 12 days 22 hours.

SAGITTA.

DOUBLE STARS.

ε	A 6th magnitude star, with an 8th magnitude companion at a distance of 92″.
ζ	Magnitudes 6 and 9 ; distance 8″. In large instruments the primary is seen to be a close double.
13	Magnitudes 6 and 7 ; distance 29″.
θ	A triple star. Magnitudes 6, 8, and 8 ; distances 11″ and 70″.

NEBULA.

M. 71	A large, though faint nebular mass.

VULPECULA.

DOUBLE STAR.

6	A wide double star. Magnitudes 4 and 5 ; distance 403″.

NEBULA AND STAR CLUSTER.

M. 27	The Dumb-Bell Nebula, visible with a very small telescope. With large instruments it appears a magnificent object (*see Plate of Nebulæ*).
4559	A rich cluster of stars, from the 6th to 13th magnitude.

CHART 7.

INTERESTING OBJECTS FOR THE TELESCOPE.

CETUS.

DOUBLE STARS.

26	Magnitudes 6 and 9; distance 16″.
42	A close double star. Magnitudes 6 and 7.
χ	A 5th magnitude star, with a 7th magnitude companion at a distance of 3″.
ν	A 5th magnitude star, with a 9th magnitude companion at a distance of 8″.
γ	A yellow-coloured 3·5 magnitude star, with a 6th magnitude companion, at a distance of 3″.
12	A 6th magnitude double star; distance 9″.
37	A 5th magnitude star, with a 7th magnitude companion, at a distance of 50″.
58	A 6th magnitude star, with a very faint companion at a distance of 3″.
61	A 6th magnitude star, distance 39″.
66	Magnitudes 6 and 8; distance 15″.
84	A 6th magnitude star, with a companion, at a distance of 5″.
94	A 5th magnitude star, with a very faint companion, at a distance of 5″.

NEBULÆ.

H. 342	A small faint nebula, with bright centre.
M. 77	A small faint nebula.

VARIABLE STARS.

o	*Mira.* One of the most remarkable variable stars in the heavens. Discovered by Fabricus in 1596. At the maximum the magnitude varies from 1·7 to 5·0, and at the minimum from the 8th to 9th magnitude. Period 331 days 8 hours 4 minutes.

COLUMBA.

DOUBLE STARS.

θ	A 5th magnitude star, with an 8th magnitude companion.
B.A.C. 2079	A 5th magnitude triple star. Distances 12″ and 70″.

STAR CLUSTERS.

H. 1009	A bright resolvable cluster.
H. 1061	A bright cluster of small stars, condensed near centre.

RED STAR.

η	A very red-coloured 4th magnitude star.

CAELUM.

DOUBLE STARS.

B.A.C. 1389	Magnitudes 6·5 and 6·5; distance 7″.
β	A 5th magnitude star, with a 7th magnitude companion.
γ	Magnitudes 5 and 7; distance 14′—forming γ^1 and γ^2.

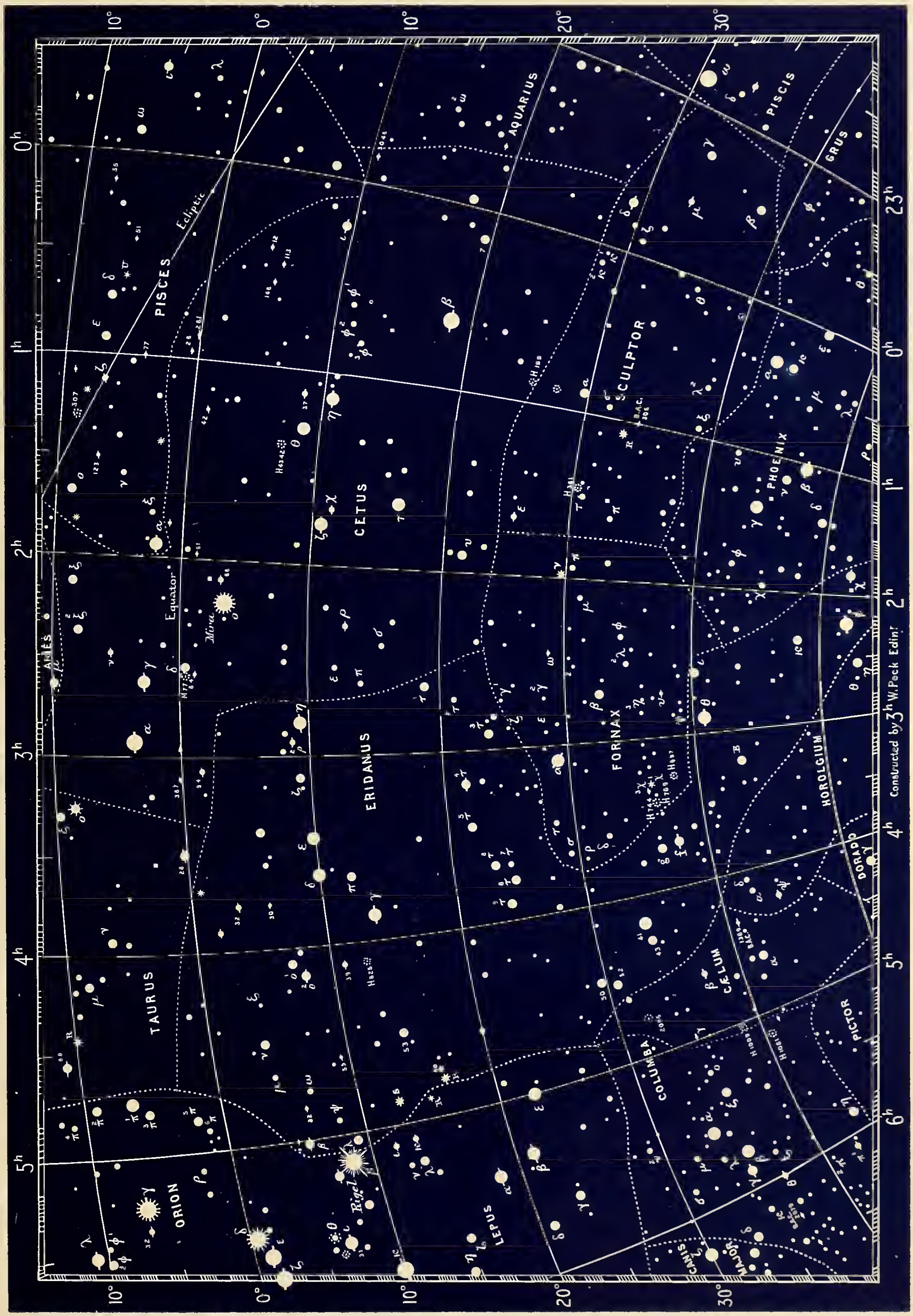
ERIDANUS.

DOUBLE STARS.

ϕ	A 3rd magnitude star, with a 5th magnitude companion, at a distance of 9″.
ρ^2	A 6th magnitude double star; distance 3″.
τ^4	A 4th magnitude star, with a faint companion at a distance of 5″.
f	Magnitudes 5·5 and 5; distance 9″.
30	A 5th magnitude star, with a faint companion at a distance of 8″.
32	Magnitudes 5 and 6; distance 6″.
39	Magnitudes 5 and 10; distance 7″.
o^2	Magnitudes 5 and 9; distance 84.″ The bright star is again double; distance 3″.
55	Magnitudes 7 and 7·5; distance 10″.
62	A 6th magnitude star, with a 9th magnitude companion; distance 63″.
θ	Magnitudes 5 and 6; distance 9″.

(Description of Chart 7 continued over the next page.)

CHART 7.


PISCES
Ecliptic
ARIES
Equator
Mira
TAURUS
ORION
Rigel
CETUS
ERIDANUS
LEPUS
AQUARIUS
SCULPTOR
FORNAX
PHOENIX
HOROLOGIUM
DORADO
CÆLUM
COLUMBA
PICTOR
CANIS MAJOR
PISCIS
GRUS
0h
1h
2h
3h
4h
5h
6h
23h
10°
0°
10°
20°
30°
Constructed by W. Peck Edinr

Side nearest the Northern Horizon in the Southern Hemisphere.

Side nearest the Southern Horizon in the Northern Hemisphere.

ERIDANUS—*continued.*

COLOURED STAR.

ψ	A remarkable blue-coloured star.

VARIABLE STARS.

60	Variable from 5th to 6th magnitude.
R	Variable from 5th to 6th magnitude.
S	Variable from magnitude 4·6 to 5·5.

NEBULA.

H. 826	Bright planetary nebula.

FORNAX.

DOUBLE STARS.

ω	Magnitudes 5 and 8; distance 11″.
υ	Magnitudes 6 and 7; distance 5″.
α	Magnitudes 3 and 8; distance 4″.
χ^3	A 6th magnitude star, with a 10th magnitude companion.

NEBULA AND STAR CLUSTERS.

H. 697	Bright nebula, with star-like centre.
H. 744	A bright cluster of small stars.
H. 769	A brilliant cluster of small stars.

VARIABLE STARS.

ν	A 6th magnitude variable star.
χ^1	Variable from 5th to 6th magnitude.

SCULPTOR.

DOUBLE STARS.

μ	A 5th magnitude star, with a 7th magnitude companion.
δ	A 4th magnitude star; distances 3″ and 74″.
B.A.C. 306	A 6th magnitude star, with a faint companion at a distance of 9″.
κ^1	Magnitudes 6 and 6; distance 1″. A close double star.
ϵ	Magnitudes 6 and 10; distance 6″.

VARIABLE STAR.

R	One of the most brilliantly-coloured stars in the heavens. The colour is of an intense scarlet. Maximum 5·8; minimum 7·7.

STAR CLUSTER AND NEBULA.

H. 162	A bright cluster of small stars, from the 12th to the 16th magnitude, with a diameter of about 5′.
H. 361	A large and faint elongated nebula, with bright centre.

CHART 8.

INTERESTING OBJECTS FOR THE TELESCOPE.

CANIS MAJOR.

DOUBLE STARS.

α	*Sirius.* This brilliant star has a 10th magnitude companion at a distance of 10″. It cannot, however, be seen with any but the largest telescopes.
6	Magnitudes 6 and 8; distance 17″.
19	A 5th magnitude star, with a 10th magnitude companion.
μ	Magnitudes 5 and 8; distance 4″.
30	A triple star. Magnitudes 4·5, 9, and 9; distances 8″ and 15″.
γ^1	Magnitudes 6 and 8; distance 17″.

STAR CLUSTERS.

M. 41	A splendid group of small stars, visible to the unaided eye as a 5th magnitude star.
H. 1512	A beautiful cluster of 10th magnitude stars.

VARIABLE STARS.

o^1	Variable from magnitude 3·8 to 4·2.
22	An exceedingly red 4th magnitude star, which is thought to vary slightly in magnitude.
27	Variable, in a long period, from magnitude 4·5 to 6·5.
R	A variable star of the *Algol* type, and of the 6th magnitude; period 1 day 3 hours 16 minutes.

HYDRA.

DOUBLE STARS.

9	A 5th magnitude star, with a faint companion at a distance of 35″.
ε	A 3rd magnitude binary star. The companion is of the 8th magnitude at a distance of 3″.
ρ (13)	A 5th magnitude star, with an exceedingly faint companion at a distance of 12″.
17	Magnitudes 6 and 7; distance 5″.
θ	A 4th magnitude star, with faint companion at a distance of 53″.
27	Magnitudes 5 and 7; distance 226″.
τ^1 (31)	Magnitudes 5 and 8; distance 65″.
λ	A 4th magnitude star, with a companion at a distance of 51″.
β	A 4th magnitude double star; distance 2″.
52	A 5th magnitude star, with a faint companion at a distance of 4″.
54	Magnitudes 5 and 7; distance 10″.

NEBULA.

H. 2102	A planetary nebula, having much the same appearance as the planet Jupiter.

VARIABLE STARS.

U	Variable from 4·5 to 6th magnitude.
R	Variability discovered in 1874 by Maraldi. The variations range from magnitude 4·5 to 10·5, in a period of 469 days.

LEPUS.

DOUBLE STARS.

ι	A 5th magnitude star, with a 10th magnitude companion at a distance of 15″.
κ	A 5th magnitude star, with an 8th magnitude companion at a distance of 3″.
β	A 3rd magnitude double star; distance 3″.
α	A 3rd magnitude double star; distance 36″.
γ	Magnitudes 4 and 7; distance 94″.

STAR CLUSTERS.

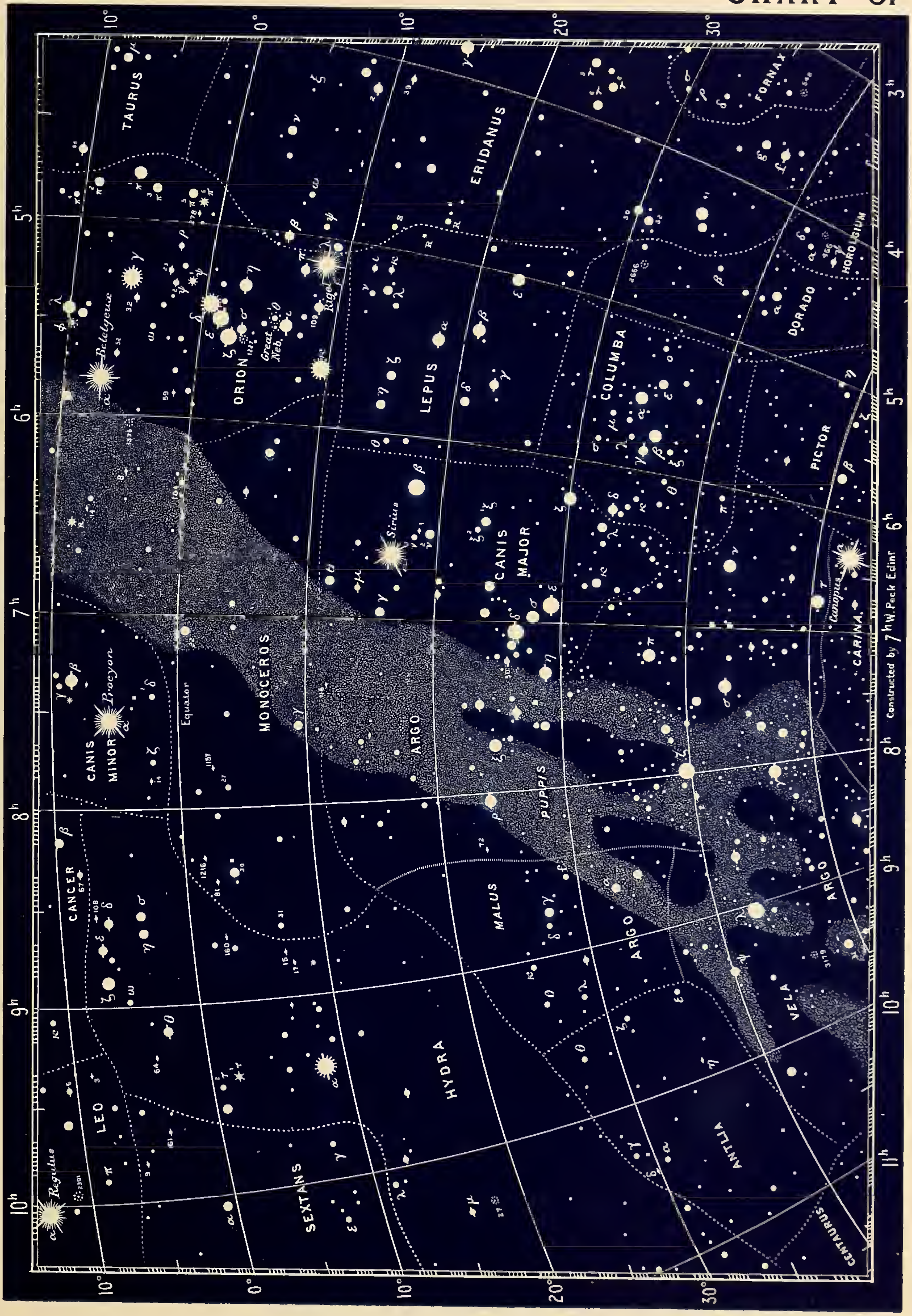
M. 79	A bright cluster, about 3′ in diameter.
H. 3780	A brilliant group of small stars, well seen with a small telescope.

VARIABLE STARS.

R	Variability discovered by Schmidt in 1855. The variations of magnitude range from the 6th to the 8·5 magnitude, in a period of 438 days.
ε	Thought to be variable.

(Description of Chart 8 continued over the next page.)

CHART 8.


TAURUS
ERIDANUS
FORNAX
ORION
Betelgeux
Rigel
Great Neb.
LEPUS
COLUMBA
DORADO
HOROLOGIUM
PICTOR
Sirius
CANIS MAJOR
Canopus
CARINA
MONOCEROS
ARGO
PUPPIS
CANIS MINOR
Procyon
Equator
CANCER
MALUS
VELA
HYDRA
LEO
Regulus
SEXTANS
ANTLIA
CENTAURUS
Constructed by T. W. Peck Edinr
3h
4h
5h
6h
7h
8h
9h
10h
11h
10°
0°
10°
20°
30°

Side nearest the Northern Horizon in the Southern Hemisphere.

Side nearest the Southern Horizon in the Northern Hemisphere.

MONOCEROS.

DOUBLE STARS.

3	A 5th magnitude star ; distance 2″.
5	A 4th magnitude star ; distance 35″.
ε (8)	Magnitudes 5 and 7 ; distance 13″.
10	A triple star. Magnitudes 5, 9, and 10 ; distances 76″ and 81″.
β (11)	A triple star. Magnitudes 5·5, 5·5, and 6 ; distances 7″ and 10″.
29	A 5th magnitude triple star ; distances 32″ and 67″ ; magnitudes 6 and 11.
30	A 4th magnitude double star ; distance 91″.

STAR CLUSTERS.

H. 1637	A group of 9th magnitude stars, visible to the naked eye.
H. 1424	A beautiful cluster of small stars, visible to the naked eye.
M. 53	A brilliant cluster of stars, half-a-degree in diameter.
	The star 10 is the centre of a beautiful cluster.

VARIABLE STARS.

T	Variability discovered by Gould in 1871. The variation is from the 6th to the 8th magnitude, in a period of 2·7 days.
S (15)	Variability discovered in 1867. Maximum magnitude, 5 ; minimum 5·5 ; period 3·4 days.
U	Variability discovered by Gould in 1873. Maximum magnitude, 6 ; minimum 7 ; period 46 days.

(ARGO) PUPPIS.

DOUBLE STARS.

B.A.C. 1964	Magnitudes 6 and 6 ; distance 2′ 30″.
V	Magnitudes 5 and 7 ; distance 13″.
π	A 3rd magnitude star, with an 8th magnitude companion.
σ	Magnitudes 3·5 and 9 ; distance 22″.
2	Magnitudes 7 and 7 ; distance 17″.
5	Magnitudes 6 and 9 ; distance 4″.

VARIABLE STARS.

L. 2	Variable from the 4th to the 6th magnitude, in a period of 136 days.
π	Variable from magnitude 2·3 to 3·3.
T	Variable from the 6th to the 7th magnitude.

CHART 9.

INTERESTING OBJECTS FOR THE TELESCOPE.

ANTLIA.

DOUBLE STARS.

ζ	A 5th magnitude star, with a 6th magnitude companion at a distance of 8″.
δ	Magnitudes 6 and 10 ; distance 11″.

VARIABLE STARS.

R	Variable from the 6th to the 8th magnitude.
γ	Thought to be variable from the 5th to the 7th magnitude.

CORVUS.

DOUBLE STARS.

δ	A 3rd magnitude star, with a faint companion at a distance of 24″.
L. 23675	A 5th magnitude star, with a 6th magnitude companion at a distance of 5″.

NEBULA.

H. 2917	A faint resolvable nebula.

CENTAURUS.

DOUBLE STARS.

D	Magnitudes 6 and 7 ; distance 4″.
γ	A close double star of the 3rd magnitude ; distance 1″.
ξ^2	A 5th magnitude star, with a 10th magnitude companion at a distance of 26″.
2	A 5th magnitude star, with a 7th magnitude companion at a distance of 5″.
Z	Magnitudes 5 and 10 ; distance 25″.
N	Magnitudes 6 and 7 ; distance 18″.
k	Magnitudes 5 and 6 ; distance 9″.
h	Magnitudes 5 and 7 ; distance 14″.
α	A well-known binary star. Magnitudes 1 and 3·5 ; distance 16″. The nearest known star to our system.
y	A triple star ; magnitudes 6, 8, and 11 ; distances 10″ and 35″.

STAR CLUSTER.

H. 3531	A cluster of small stars, 20′ in diameter, visible to the naked eye. One of the finest objects in the heavens.

SEXTANS.

DOUBLE STARS.

35	Magnitudes 6 and 8 ; distance 7″.
41	Magnitudes 5 and 8 ; distance 27″.
9	Magnitudes 6 and 7 ; distance 50″ ; colours, yellow and blue.

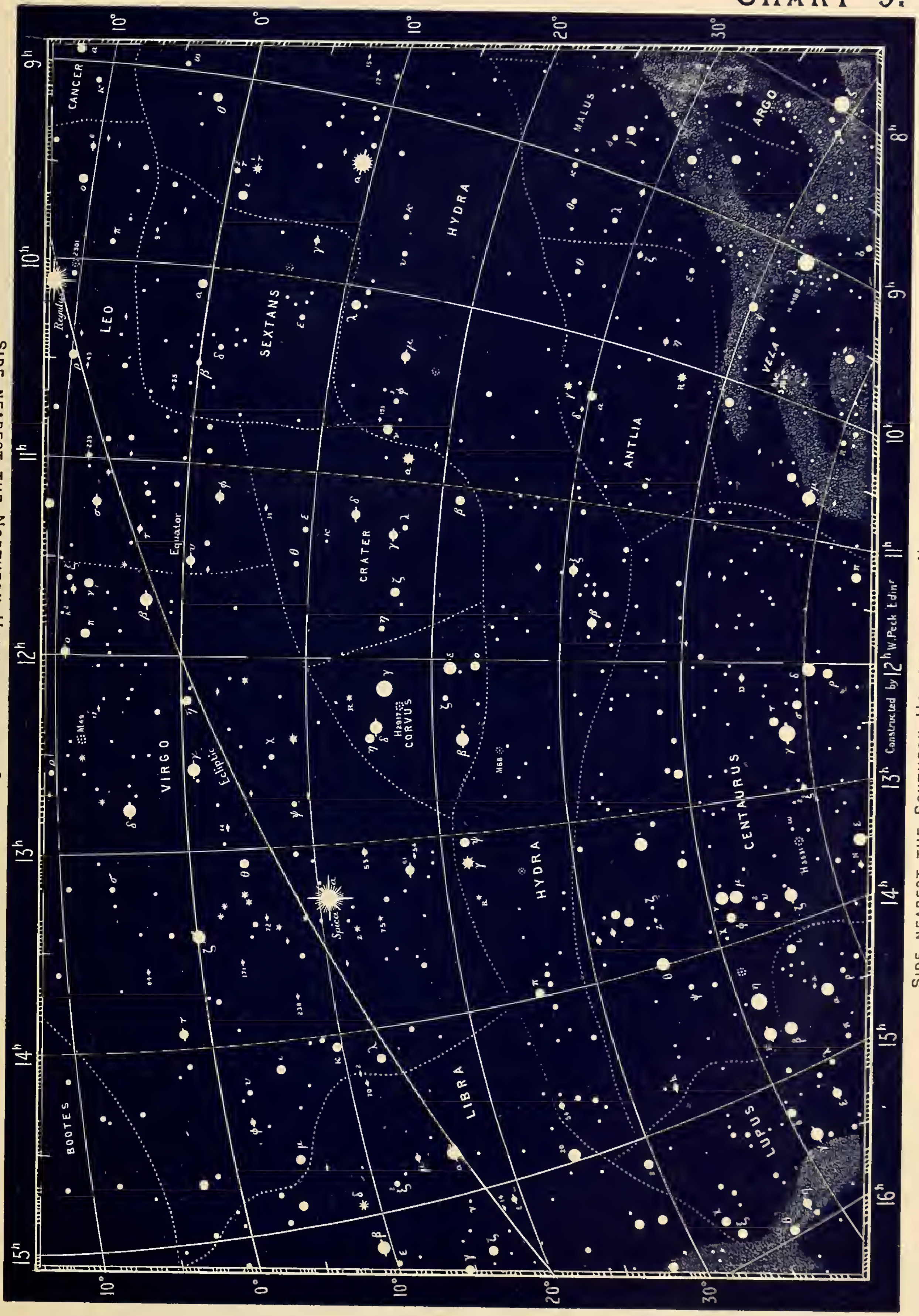
VIRGO.

DOUBLE STARS.

γ	A remarkable binary star ; distance 5″; magnitudes 3·5 and 3·5 ; period 185 years.
d^1	A 6th magnitude double star, with a faint companion at a distance of 4″.
k	A 6th magnitude star, with a companion at a distance of 21″
θ	Triple star. Magnitudes 5, 9, and 10 ; distances 7″ and 71″.
53	Magnitude 5 ; distance 71.
54	Magnitudes 6·5 and 7″ ; distance 6″.
72	Magnitudes 6 and 9 ; distance 30″
75	A 6th magnitude star, with a companion, at a distance of 73″.
ο (84)	A 6th magnitude star, with an 8th magnitude companion at a distance of 3″ ; colours, yellow and blue.
τ (93)	A 4th magnitude star, with a companion, at a distance of 80″
φ	Magnitudes 5 and 9 ; distance 5″.
17	Magnitudes 6 and 9 ; distance 20″.

(Description of Chart 9 continued over the next page.)

CHART 9.


9h
10h
11h
12h
13h
14h
15h
16h
8h
10°
0°
10°
20°
30°
CANCER
LEO
Regulus
SEXTANS
HYDRA
MALUS
ARGO
VELA
ANTLIA
CRATER
CORVUS
VIRGO
Spica
Equator
Ecliptic
CENTAURUS
LIBRA
LUPUS
BOOTES
M49
M68
Constructed by W. Peck Edinr

Side nearest the Northern Horizon in the Southern Hemisphere.

Side nearest the Southern Horizon in the Northern Hemisphere.

VIRGO—*continued.*

NEBULÆ.

M. 60	Extremely faint nebula.
M. 49	A bright resolvable nebula.
M. 88	Spiral nebula of the Earl of Rosse.
H. 3132	A large but faint nebula.

VARIABLE STARS.

R	Variability discovered by Harding in 1809. Maximum magnitude, 6 to 7 ; minimum 11.
S	Discovered by Hind in 1802. Maximum magnitude, 6 to 8 ; minimum 12. Period 374 days.

CHART 10.

INTERESTING OBJECTS FOR THE TELESCOPE.

CORONA AUSTRALIS.

DOUBLE STARS.

κ	Magnitudes 6 and 6 ; distance 22″.
γ	A 5th magnitude binary star ; distance 3″ ; period 82 years.

LUPUS.

DOUBLE STARS.

G. 1614	Magnitudes 6 and 9 ; distance 4″.
a	A 5th magnitude star, with a 7th magnitude companion at a distance of 20″.
κ	Magnitudes 4 and 6 ; distance 27″.
ζ	A 4th magnitude star, with a companion at a distance of 72″.
μ	A triple star. Magnitudes 6, 6, and 8 ; distances 2″ and 23″.
ε	Magnitudes 4 and 9 ; distance 26″.
D	A close 5th magnitude double star. The companion is of the 7th magnitude, and at a distance of 2″.
ξ	Magnitudes 6 and 6 ; distance 11″.
η	Magnitudes 4 and 8 ; distance 15″.
f	Magnitudes 5 and 9 ; distance 3″.

STAR CLUSTERS.

H. 3922	A bright cluster of faint stars, from the 9th to the 13th magnitude.
H. 4066	A faint planetary nebula.
H. 4100	A cluster of small stars, of the 11th magnitude.

NORMA.

DOUBLE STARS.

B.A.C. 5218	Magnitudes 6 and 9 ; distance 21″.
ι^1	Magnitudes 5 and 8 ; distance 10″.
ε	Magnitudes 5 and 7 ; distance 24″.

STAR CLUSTERS.

H. 4162	A large and beautiful cluster of small stars, 20′ in diameter.
H. 4170	A coarse and brilliant cluster of stars, from the 7th to the 10th magnitude.
H. 4184	A bright cluster of small stars.

OPHIUCHUS.

DOUBLE STARS.

ψ	A 5th magnitude star, with a faint companion at a distance of 33″.
λ	A close binary star ; period 234 years ; distance 2″.
19	Magnitudes 6 and 8 ; distance 22″.
36	Magnitudes 5·75 and 5·75 ; distance 5″. A binary star.
ο (39)	Magnitudes 6 and 7 ; distance 12″.
53	Magnitudes 6 and 8 ; distance 41″.
61	Magnitudes 6 and 6 ; distance 20″.
67	A 4th magnitude star, with an 8th magnitude companion at a distance of 58″.
τ	A close binary star of the 5th magnitude ; period 218 years. The companion is of the 6th magnitude.
70	A binary star of the 4th magnitude. Period 94 years ; distance 3″.
74	A 5th magnitude double star ; distance 28″.

VARIABLE STARS.

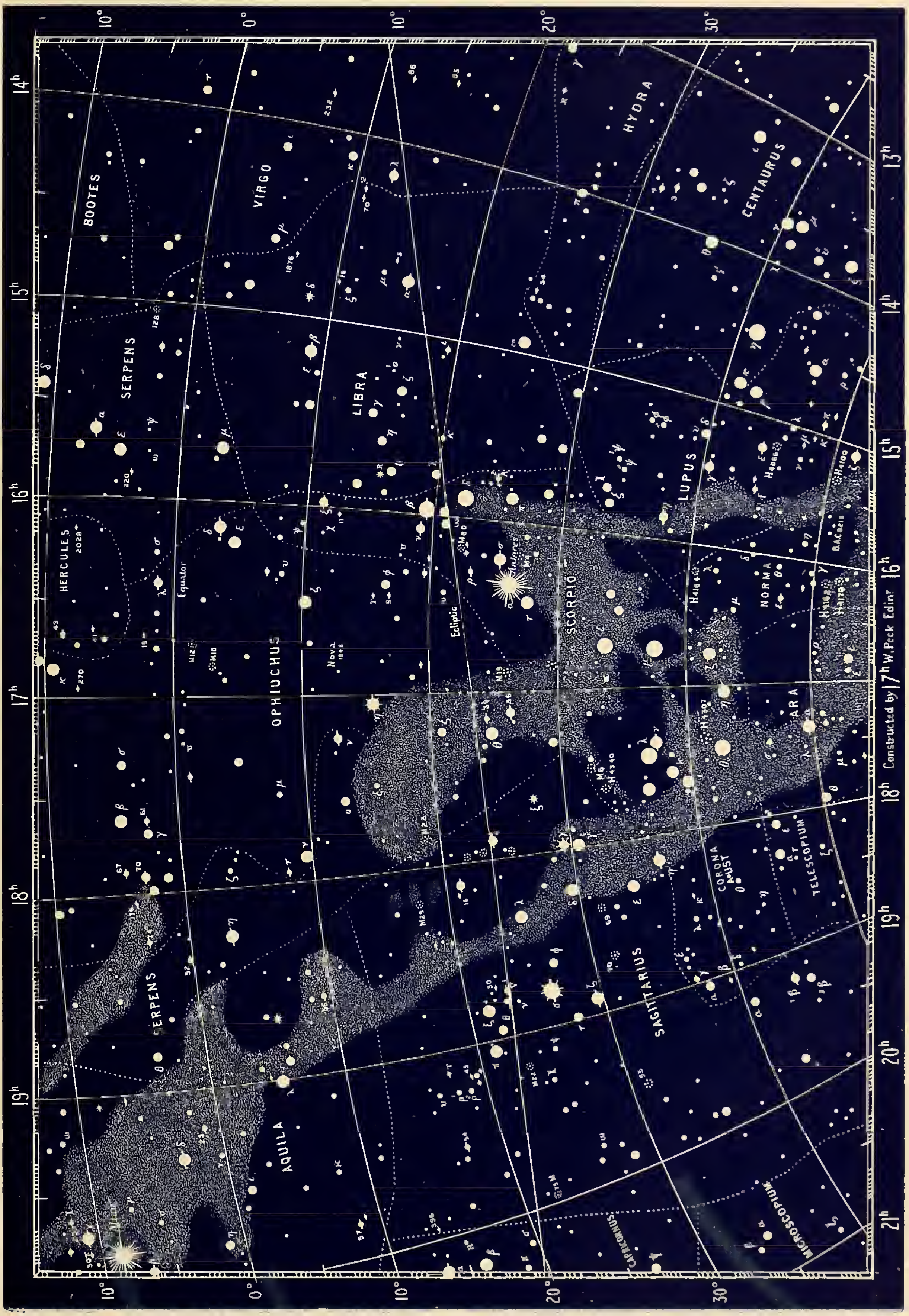
	Nova (*of* 1848). A temporary star, which appeared in April, 1848 ; the maximum brilliancy was of the 5th magnitude ; the present magnitude being about 12·5.
U	Discovered to be variable in 1881 from the 6th to the 7th magnitude, in the short period of 21 hours.

STAR CLUSTERS.

M. 23	A beautiful cluster of 10th magnitude stars.
M. 12	A resolvable cluster of small stars.
M. 10	A brilliant cluster of small stars.
M. 19	A large mass of minute stars.

(Description of Chart 10 continued over the next page.)

Side nearest the Northern Horizon in the Southern Hemisphere.


14h
15h
16h
17h
18h
19h
13h
14h
15h
16h
17h
18h
19h
20h
21h
10°
0°
10°
20°
30°
BOOTES
VIRGO
HYDRA
CENTAURUS
SERPENS
LIBRA
LUPUS
HERCULES
Equator
OPHIUCHUS
Nova 1848
Ecliptic
Antares
SCORPIO
NORMA
ARA
CORONA AUST
TELESCOPIUM
SERPENS
SAGITTARIUS
AQUILA
CAPRICORNUS
MICROSCOPIUM
Constructed by W. Peck Edinr

Side nearest the Southern Horizon in the Northern Hemisphere.

SAGITTARIUS.

DOUBLE STARS.

μ	A triple star of the 4th magnitude; distances 40″ and 45″. The magnitudes of the companions are 9 and 10.
16	Magnitudes 6 and 9 ; distance 6″.
η	A 3rd magnitude double star ; distance 4″.
ν^1	A 5th magnitude double star ; distance 29″.
β^1	Magnitudes 4 and 7 ; distance 29″.
54	A triple star. Magnitudes 5, 8, and 8 ; distances 36″ and 46″.

VARIABLE STARS.

ξ	Variable from the 4th to the 6th magnitude, in a period of 7 days.
w	Discovered in 1866 to be variable from the 5th to the 6th magnitude, in a period of 7½ days.
y	Variable from magnitude 5·5 to 6·5, in a period of 5 days 18 hours.
51	Variable from magnitude 5 to 6·5.

STAR CLUSTERS.

M. 24	A cluster of faint stars.
M. 22	A beautiful cluster of faint stars. Well seen with a small telescope.
M. 25	A coarse and brilliant cluster of small stars.
M. 75	A resolvable cluster, with bright centre.
M. 8	A magnificent object for a small telescope.

SCORPIO.

DOUBLE STARS.

A (2)	Magnitudes 5 and 7 ; distance 3″.
ξ (51)	A close binary star of the 4th magnitude ; period 96 years.
β	A triple star. Magnitudes 2, 5, and 10 ; distances 13″ and 1″.
11	A 6th magnitude double star ; distance 4″.
σ	Magnitudes 3 and 9 ; distance 20″.
α	*Antares.* Magnitudes 1 and 7 ; distance 4″. Colours, fiery red and green.
ν	Magnitudes 4 and 7 ; distance 40″.

STAR CLUSTERS.

M. 80	A rich and condensed mass of stars, shaped somewhat like a comet.
M. 4	A large and faint resolvable cluster.
H. 4307	A large and dense cluster of minute stars.
M. 6	A bright cluster of stars, from the 7th to the 10th magnitude.
H. 4340	A brilliant cluster of stars, from the 7th to the 12th magnitude.

CHART 11.

INTERESTING OBJECTS FOR THE TELESCOPE.

AQUARIUS.

DOUBLE STARS.

ζ	A binary star. Magnitudes 4 and 4; distance 4″. Well seen with a small telescope.
12	Magnitudes 6 and 7; distance 3″.
ψ	Magnitudes 5 and 9; distance 50″.
107	A supposed binary star. Magnitudes 6 and 7; distance 6″.
29	Magnitudes 6 and 8; distance 5″.
41	Magnitudes 6 and 8; distance 5″.
94	A 5th magnitude star, with a 7th magnitude companion at a distance of 14″.
τ^1	Magnitudes 6 and 9; distance 30″.
53	Magnitudes 6 and 6; distance 10″.

VARIABLE STARS.

τ (71)	Thought to be variable from magnitude 4·5 to 6.
R	An irregular variable star discovered in 1811. Maximum magnitude 6; minimum 10; period about 390 days.

NEBULÆ.

M. 2	A large round nebula. Well seen with a small telescope.
H. 462	An elliptical planetary nebula, of a pale blue colour, which has been shown by the spectroscope to be a mass of incandescent gas.

CAPRICORNUS.

DOUBLE STARS.

π	A 5th magnitude star, with a companion, at a distance of 3″.
ρ (11)	Magnitudes 5 and 7; distance 4″.
α	A fine object for a small telescope. Magnitudes 3 and 4; distance 370″. Both stars are of a yellow colour.
β	Magnitudes 3 and 7; distance 205″; colours, yellow and light blue. Also a fine object for a small telescope.
o^2	Magnitudes 6 and 7; distance 22″.

NEBULA.

M. 30	A fairly bright comet-like nebula.

MICROSCOPIUM.

DOUBLE STAR.

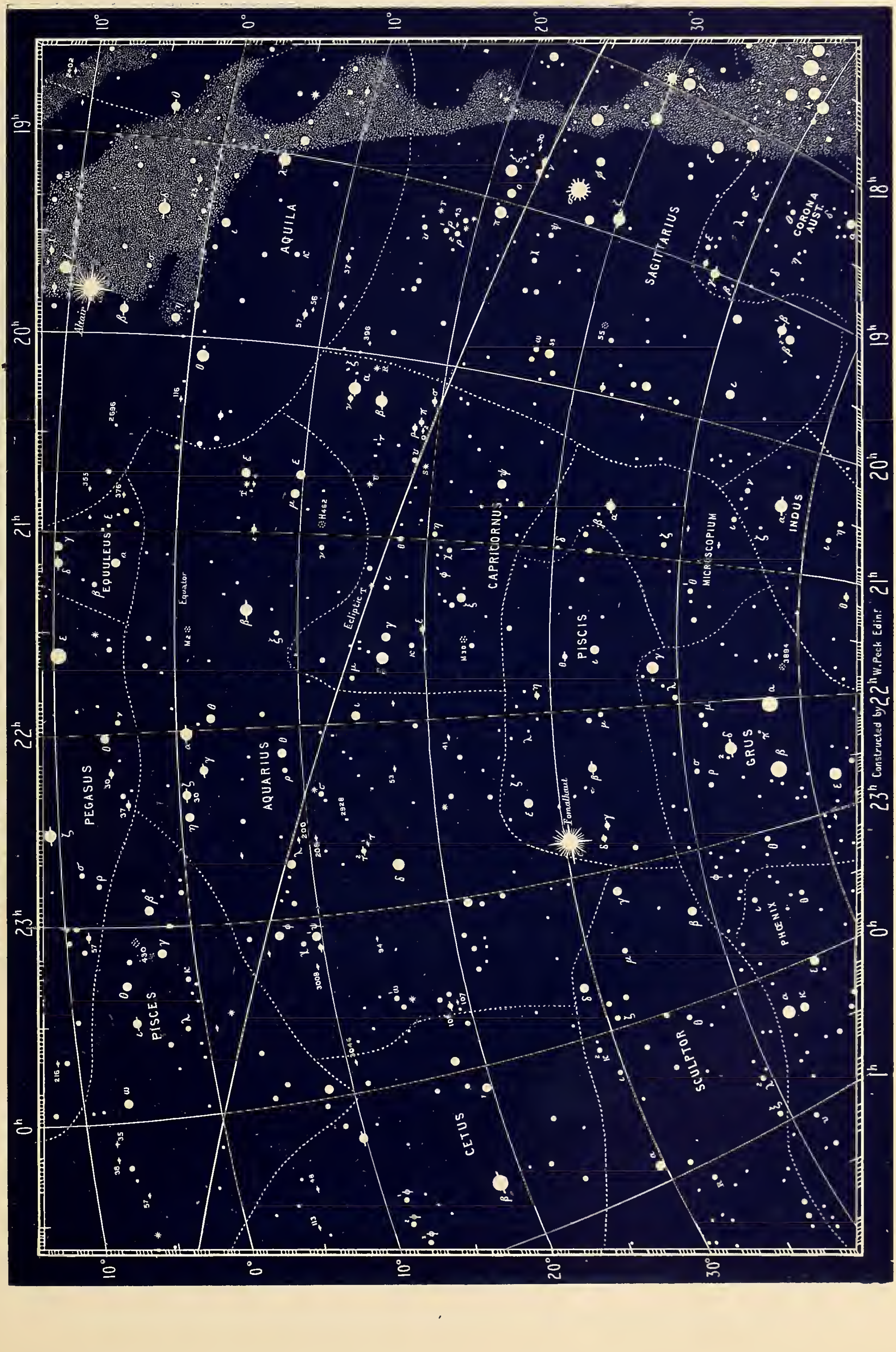
α	A 5th magnitude star, with a 9th magnitude companion, at a distance of 22″.

PISCIS AUSTRALIS.

DOUBLE STARS.

θ	A 5th magnitude star, with an exceedingly faint companion, at a distance of 25″.
η	A close 5th magnitude double star. The distance of the 6th magnitude companion from the primary is less than 2″.
β	Magnitudes 4 and 6; distance 29″.
γ	A 4th magnitude star, with a faint companion, at a distance of 4″.
δ	Magnitudes 4 and 9; distance 5″.

CHART 11.


AQUILA
SAGITTARIUS
CORONA AUST.
INDUS
MICROSCOPIUM
CAPRICORNUS
PISCIS
GRUS
PHŒNIX
SCULPTOR
CETUS
PISCES
PEGASUS
AQUARIUS
EQUULEUS
Equator
Ecliptic
Altair
Fomalhaut
M2
M30
H462
Constructed by W. Peck Edinr
18h
19h
20h
21h
22h
23h
0h
1h
10°
0°
10°
20°
30°

Side nearest the Northern Horizon in the Southern Hemisphere.

Side nearest the Southern Horizon in the Northern Hemisphere.

CHART 12.

INTERESTING OBJECTS FOR THE TELESCOPE.

ARA.

DOUBLE STARS.

H. 4876	Magnitudes 6 and 7; distance 10″.
H. 4901	Magnitudes 6 and 7; distance 3″.
H. 4949	A 6th magnitude triple star. Distances 3″ and 104″.

APUS.

VARIABLE STAR.

θ	Variable from the 5th to the 6th magnitude.

CIRCINUS.

DOUBLE STAR.

α	Magnitudes 4 and 9; distance 16″.

CRUX.

DOUBLE STARS.

α	A triple star. Magnitudes 1, 2, and 6; distances 6″ and 90″.
γ	A 2nd magnitude star, with a 5th magnitude companion at a distance of 100″.

CHAMAELEON.

DOUBLE STAR.

ϵ	Magnitudes 5 and 7; distance 2″.

(ARGO) CARINA.

DOUBLE STARS.

ν	Magnitudes 3 and 7; distance 5″.
t	Magnitudes 5 and 7; distance 15″.

VARIABLE STARS.

g	Variable from the 4th to the 6th magnitude.
R	A remarkable variable star, varying from magnitude 4·5 to 10 in a period of 313 days.
l	Variable from the 4th to the 5th magnitude in a period of 31 days.

STAR CLUSTER.

H. 2167	A splendid cluster of small stars, visible to the naked eye.

DORADO.

VARIABLE STAR.

R	A very red star, which varies from magnitude 5 to 6·5.

GRUS.

RED STAR.

π	A very red star of the 6th magnitude.

INDUS.

DOUBLE STAR.

θ	A 5th magnitude double star, with a 7th magnitude companion, at a distance of 4″.

MUSCA.

DOUBLE STARS.

H. 4498	A 6th magnitude double star; distance 9″.
β	A very close double star; distance less than 1″. Only to be seen with a very powerful telescope.
θ	Magnitudes 6 and 8; distance 5″.

NORMA.

DOUBLE STAR.

ϵ	Magnitudes 5 and 7; distance 27″.

OCTANS.

DOUBLE STARS.

μ^2	Magnitudes 6 and 7; distance 20″.
λ	Magnitudes 6 and 8; distance 4″.

(Description of Chart 12 continued over the next page.)

PICTOR.

DOUBLE STARS.

ι	Magnitudes 6 and 6·5; distance 12″.
θ	Magnitudes 6 and 7; distance 39″.
H. 77	Magnitudes 7 and 7; distance 6″.
H. 3835	Magnitudes 6 and 6; distance 3″.

PAVO.

DOUBLE STAR.

H. 5222	Magnitudes 6 and 6; distance 3″.

VARIABLE STAR.

κ	Variable from the 4th to the 5th magnitude, in a period of 9 days.

STAR CLUSTER.

H. 4467	A cluster of very faint stars, visible to the naked eye.

PHOENIX.

DOUBLE STARS.

θ	Magnitudes 6 and 7; distance 5″.
ζ	Magnitudes 4 and 8; distance 6″.
β	A 3rd magnitude star, with an exceedingly faint companion, at a distance of 30″.

RETICULUM.

DOUBLE STARS.

D. 12	Magnitudes 6 and 8; distance 19″.
θ	Magnitudes 6 and 7; distance 5″.

TELESCOPIUM.

DOUBLE STARS.

H. 5041	Magnitudes 6·5 and 6·5; distance 3″.
D. 227	Magnitudes 6 and 7; distance 23″.

TRIANGULUM.

VARIABLE STAR.

R	Variable from the 6th to the 7th magnitude, in a period of 3 days 9 hours 35 minutes.

TOUCAN.

DOUBLE STARS.

β	Magnitudes 5 and 5; distance 28″.
λ	Magnitudes 6 and 8; distance 21″.

VOLANS.

DOUBLE STARS.

ε	Magnitudes 4 and 7; distance 6″.
δ	A 4th magnitude star, with a very faint companion, at a distance of 7″.
β	Magnitudes 4 and 4; distance 28″.
λ^1	Magnitudes 6 and 7; distance 21″.
H. 3416	Magnitudes 7 and 7; distance 4″
κ	Magnitudes 5 and 7; distance 5″.
γ	Magnitudes 5 and 7; distance 13″.

STAR CLUSTER.

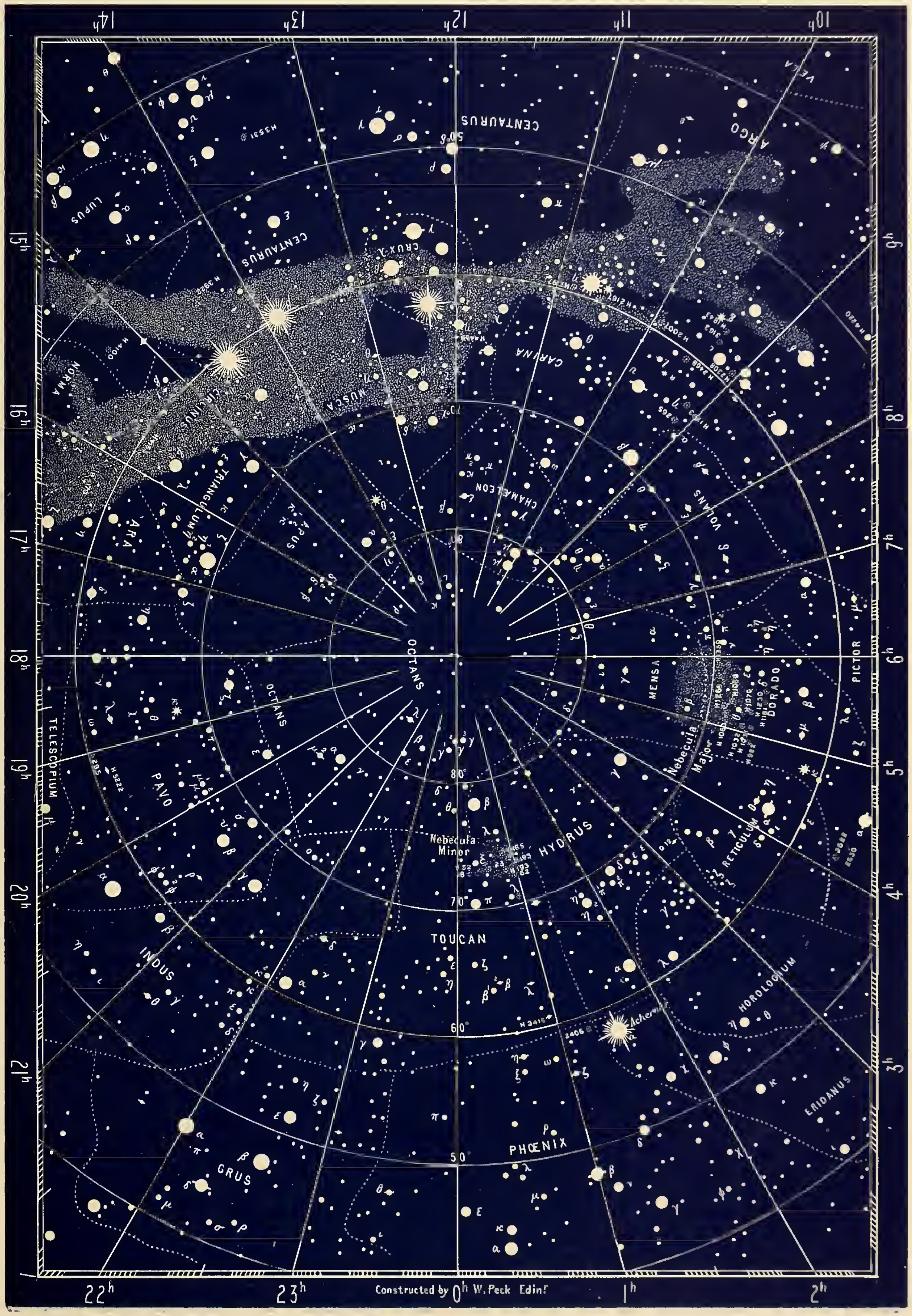
H. 52 (ξ)	One of the grandest clusters in the heavens, visible to the naked eye, as a 4th magnitude star.

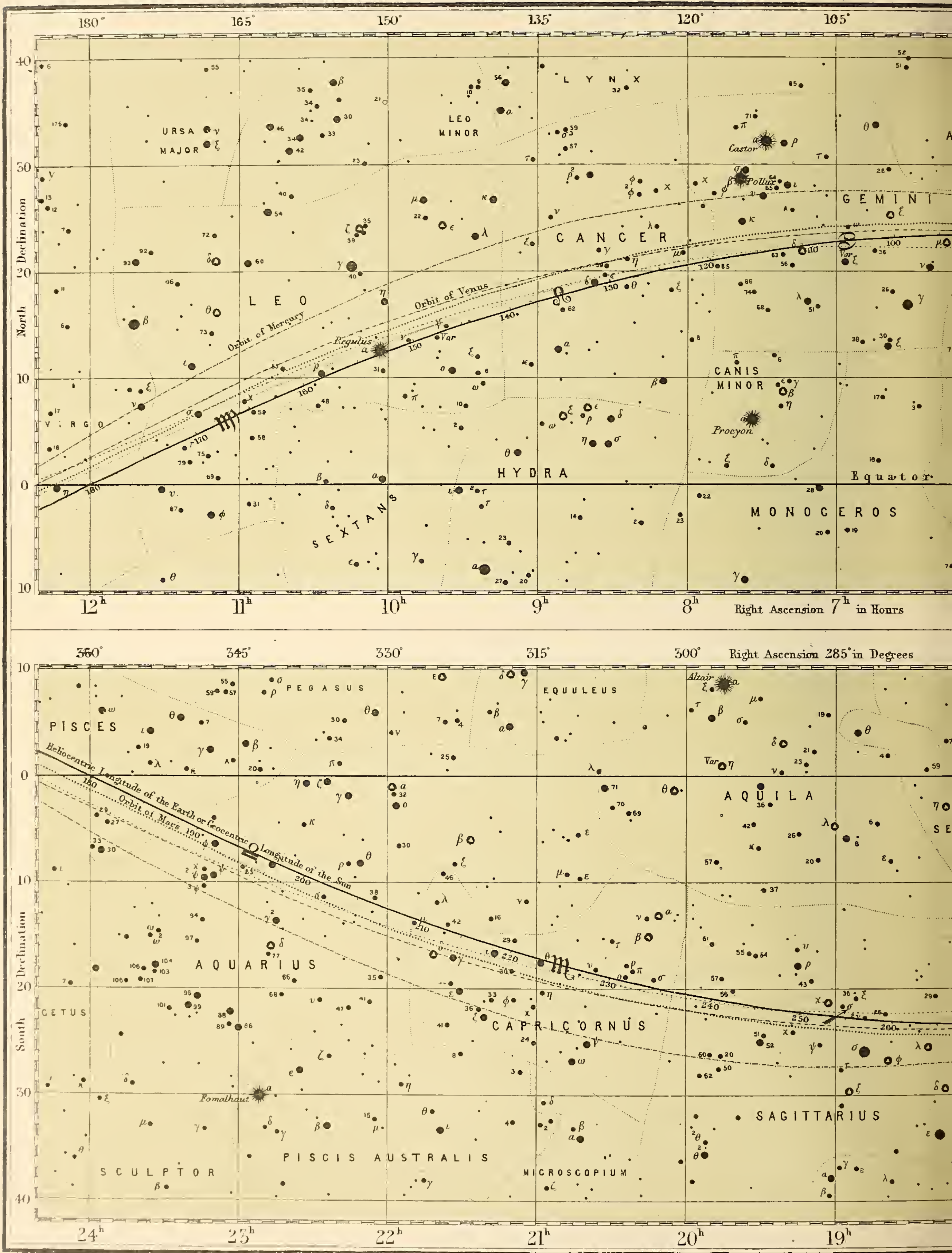
(ARGO) VELA.

DOUBLE STARS.

γ	A triple star. Magnitudes 2, 5, and 7; distances 41″ and 62″.
A	A 5th magnitude triple star. Distances 4″ and 20″.
b	A 4th magnitude double star, with an 11th magnitude companion, at a distance of 7″.
H. 4188	Magnitudes 6 and 7; distance 3″.
H. 4220	A 5th magnitude double star; distance 3″.
B.A.C. 3396	Magnitudes 6 and 8; distance 6″.
J	A triple star. Distances 7″ and 37″. Magnitudes 5, 8, and 9.
s	Magnitudes 6 and 6; distance 14″.
T	A triple star. Magnitudes 5, 10, and 10; distances 7″ and 37″.

CHART 12.

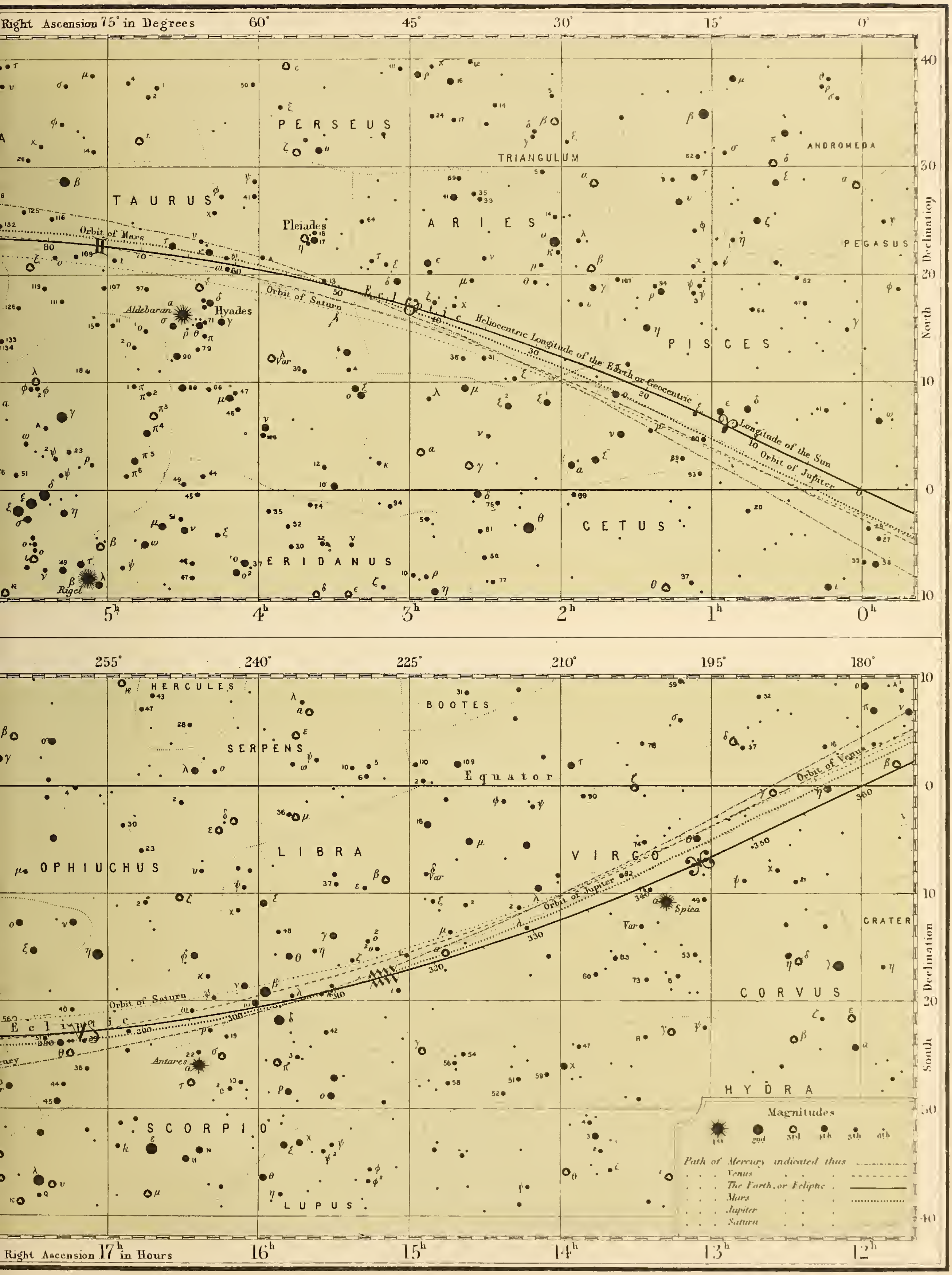

14h
13h
12h
11h
10h
15h
16h
17h
18h
19h
20h
21h
9h
8h
7h
6h
5h
4h
3h
22h
23h
0h
1h
2h
CENTAURUS
ARGO
VELA
LUPUS
CRUX
CARINA
MUSCA
NORMA
CIRCINUS
TRIANGULUM
ARA
APUS
CHAMÆLEON
VOLANS
OCTANS
MENSA
DORADO
PICTOR
Nebecula Major
TELESCOPIUM
PAVO
HYDRUS
Nebecula Minor
RETICULUM
INDUS
TOUCAN
HOROLOGIUM
Achernar
ERIDANUS
PHŒNIX
GRUS
80
70
60
50
Constructed by W. Peck Edinr



180°
165°
150°
135°
120°
105°
North Declination
40
30
20
10
0
10
URSA MAJOR
LEO MINOR
LYNX
Castor
Pollux
GEMINI
CANCER
LEO
Orbit of Mercury
Orbit of Venus
Regulus
CANIS MINOR
Procyon
VIRGO
HYDRA
Equator
SEXTANS
MONOCEROS
12h
11h
10h
9h
8h
Right Ascension 7h in Hours
360°
345°
330°
315°
300°
Right Ascension 285° in Degrees
PEGASUS
EQUULEUS
Altair
PISCES
Heliocentric Longitude of the Earth or Geocentric Longitude of the Sun
Orbit of Mars
AQUILA
AQUARIUS
CETUS
CAPRICORNUS
Fomalhaut
SAGITTARIUS
PISCIS AUSTRALIS
SCULPTOR
MICROSCOPIUM
South Declination
24h
23h
22h
21h
20h
19h

onstructed · William

CHART 13.


Right Ascension in Degrees
75°
60°
45°
30°
15°
0°
PERSEUS
TRIANGULUM
ANDROMEDA
TAURUS
Pleiades
ARIES
PEGASUS
Orbit of Mars
Orbit of Saturn
Ecliptic
Aldebaran
Hyades
Heliocentric Longitude of the Earth or Geocentric Longitude of the Sun
Orbit of Jupiter
PISCES
Var
CETUS
ERIDANUS
Rigel
North Declination
5h
4h
3h
2h
1h
0h
255°
240°
225°
210°
195°
180°
HERCULES
BOOTES
SERPENS
Equator
Orbit of Venus
LIBRA
OPHIUCHUS
VIRGO
Orbit of Jupiter
Spica
CRATER
Orbit of Saturn
Ecliptic
CORVUS
Antares
SCORPIO
HYDRA
LUPUS
South Declination
Magnitudes
1st
2nd
3rd
4th
5th
6th
Path of Mercury indicated thus
Venus
The Earth, or Ecliptic
Mars
Jupiter
Saturn
Right Ascension in Hours
17h
16h
15h
14h
13h
12h

Engraved by Archibald & Peck Edin.

INDEX.

PAGE
Aberration of Light, 15
„ constant of, 16
Achromatic Telescope, 96
Achromatism, Tests for, 109
Adams, 59
Aërolites, 70
Algol, Variation of Magnitude of, 26
Almegest, Ptolemy's, 112
Altitude and Azimuth Instrument, 107
Andromeda, Nebula of, 29
Andromedes I. and II. (Meteor Systems), 69
Annual Motion of the Earth, 12
Annular Nebula in Lyra, 29
Anomalistic Month, 73, 80
Apertures of Telescopes, dividing power of, 111
Apogee, 74
Appian, 67
Apsides, Line of, 73
Aquarids (Meteor System), 69
Aquilids (Meteor System), 69
Aratos, 3, 112
Argelander, 114
Argûs η, the Variable Star, 26
Ariel, the inner Satellite of Uranus, 62
Aries, first point of, 15
Arietids (Meteor System), 69
Aristarchus, 33, 91
Aristillus, 91
Asteroids, or Minor Planets, 51
„ Mass of all the, 52
„ Principal Facts about the, 61, 62
Astrolabe, 92
Atlas, and the Sphere of Eudoxos, 1, 3
Attraction, Intensity of, on the Moon, 75; Planets, 62; Sun, 35
Aurigids (Meteor System), 69
Auzot, 100
Axis of the Earth, Direction of, 13
„ „ Disturbed by Precession, 13

B.A.C., contraction for British Association Star Catalogue, 114
Bayer, 112, 115
Berosus, Hemisphere of, 90
Bessel, 19, 108
Biela's Comet, 68, 70
Binary Stars, 24, 25
Bode's Law, 51, 59
Bradley, 15, 16
Brahé, Tycho, 63, 93, 100, 112
British Association Catalogue of Stars, 114

PAGE
Calypso, the outer Satellite of Jupiter, 62
Cassegrainian Telescope, 98
Cassini, 34
Cassini's Division of Saturn's Ring, 56, 57
Catalogue of Stars, 127
Ceres (Minor Planet), 51
Charts of the Stars, Explanation of, 112, 114, 115
Chromatic Aberration, 95
„ „ Tests for, 109
„ Telescope, 94, 95
Chromosphere, the Solar, 37
Chronograph, 101
Circle, Origin of the Division of the, 2, 91
„ Meridian or Transit, 102
Classification of Stars, 23
Clepsydra, 93
Clocks, Observatory, 102
„ Mean Time and Sidereal, 103
Clusters of Stars, 28, 29
Coma of Comets, 67
Comets, 63
„ Acceleration of, 66
„ Belonging to the Solar System, Table of, 65
„ Chemical Elements in, 67
„ Classes of, 65
„ Coma of, 67
„ Connection with Meteors, 69, 70, 71
„ Constituent Parts of, 66, 67
„ Contraction of Head when near the Sun, 66
„ Elements required for calculating Paths of, 63
„ Hyperbolic, 64
„ Light of, 67
„ Origin of, 71
„ Parabolic, 65, 66
„ Periodic, 64, 65, 66, 71
„ Physical Characteristics of, 68
„ Tails or Trains of, 67
„ „ Curvature, Density, &c., 68
Compensation Pendulum, 103
Constellations, Alterations in appearance, 17
„ Probable Origin of the, 4
„ Figures of the, 2, 4
„ List of the, 113
„ Used in the Star Charts, 118
Copernicus, 13, 93
Copernicus (Lunar Crater), 78
Corona, the Solar, 38
Coronids (Meteor System), 69
Crab Nebula, 29
Crape Ring of Saturn, 56, 57
Cygnids (Meteor System), 69

PAGE
D, Line in Solar Spectrum, 106
D.M., contraction for Durchmusterung Star Catalogue of Argelander, 114
Day, Sidereal and Solar, 46
Declination, Definition of, 14
Degree, Origin of, 2, 14, 91
Deimos, the outer Satellite of Mars, 50, 62
Density, Definition of, 35
„ of the Planets, Sun, &c., *see under the heading of each.*
Diameters of Lunar Craters and Walled Plains, 79
„ of the Planets, Sun, Stars, &c., *see under the heading of each.*
Diffraction Grating, 106
Dione, fourth Satellite of Saturn, 62
Distances of Moon, Planets, Sun, &c., *see under the heading of each.*
Diurnal Rotation of the Earth, 11
Doerfel, 63
Dollond, 96
Donati's Comet, 68
Double Stars, 24
Draconids (Meteor System), 69
Dumb-bell Nebula, 29
Durchmusterung Star Catalogue, 114

Earth, 45
„ Apparent Angular Velocity of, 73
„ Eccentricity of Orbit for 200,000 years, 46
„ Form of, 45
„ Length of a Degree of Latitude at various Distances from the Equator, 45
„ Motions of, 11
„ Principal Facts about, 61, 62
„ Rotation Period of, 11
„ Velocity in Orbit, 15, 45
Eccentricity, Definition of, 45, 46
„ of the Earth's Orbit, 46
Eclipses, 82
„ Number in a Saros 85, 86
„ „ „ Year, 86
„ Recurrence of Saros, 85
„ Relative Frequency of Solar and Lunar, 85
„ Seasons, 85
„ Year, 85
Eclipses, Lunar, 86
„ „ Apparent Diameter of Earth's Shadow in, 87
„ „ Duration of, 87
„ „ Number in a Year, 86
„ Recurrence of the Saros, 85

PAGE
Eclipses, Lunar, till 1900 A.D., Table of, 84
Eclipses, Solar, 88
„ „ Annular, 88
„ „ Duration of, 89
„ „ Diameter of Shadow Cone, 88
„ „ Distance of Vertex Lunar Shadow from the Earth, 89
„ „ Partial and Total, 89
„ „ till 1900 A.D., Table of, 83
„ „ Velocity of Moon's Shadow in, 89
Ecliptic, The, defined, 14
„ Limits, Lunar, 87; Solar, 88
„ Observed Obliquity of, for 3000 years, 47
Elements, Chemical, recognised in the Sun, &c., *see under separate heading of each.*
Elements of a Comet's Orbit, 63
Enceladus, the second Satellite of Saturn, 62
Encke's Comet, 66
Enoptron of Eudoxos, 3
"Envelopes" in the Head of a Comet, 66, 67
Equation of Time, 121
Equator, the Celestial, 11, 14, 91, 92, 103
Equatorial Acceleration of the Sun's Motion, 36
Equatorial Telescopes, 103
„ Mounting, 104
„ Adjustment for small Telescope, 110
Equinoctial, *see* Equator.
Equinoxes, Dates of the, 13
„ Precession of, 2, 13
Eratosthenes, his Meridian Instrument, 91
Eruptive Prominences, 37
Escapement of Clock, 103
Eudoxos, Sphere of, 2, 112
Europa, the second Satellite of Jupiter, 62
Eye-pieces, Telescopic, 110

Faculae, 37
Families of Small Comets, 71
Finder for Telescopes, 110
Flamsteed, 114
Force, Repulsive, Action on Comets, 68
Foucault, 99
Fraunhofer, 96, 105
Fraunhofer's Lines, 106

Galaxy, The, or Milky Way, 30
Galileo, 94, 102
Ganymede, the third Satellite of Jupiter, 54, 62
Gascoigne, 100
Geminids (Meteor System), 69

PAGE
Geocentric Latitude and Longitude, 14
Gnomon, The, 90
Godfrey, 108
Graduation Errors of a Circle, 102
Graham, 103
Granules, 37
Grating, Diffraction, 106
Gravity, Force of, 35
„ „ „ on the Planets, 62
Great Nebula in Orion, 29
Gregorian Telescope, 97
Gregory, 97
Groups of Stars, 28

Hadley, 98, 108
Halley, 17, 64
Halley's Comet, 64, 68
Harmonic Law, 58
Heat received by the Planets from the Sun, 61
Heliocentric Longitude, 116
Hemisphere of Berosus, 91
Henderson and the Parallax of α Centauri, 19
Herschel, Sir W., 31, 58, 98
Hesperus, the Evening Star, 43
Hevelius, 63, 76
Hilda (Minor Planet), 51
Hipparchus, 13, 91, 92, 112, 114
Hooke, 16, 100, 108
Huygens, 95, 100, 102
Hydrogen, in the Solar Chromosphere, 37
„ in the Stars, 22
Hyperion, the Seventh Satellite of Saturn, 62

Intra-Mercurial Planets, 40
Instruments of the Ancients, 90
Io, the first Satellite of Jupiter, 62
Iron Meteors, 70
„ in the Sun, 106

Japetus, the outermost Satellite of Saturn, 62
Juno (Minor Planet), 51
Jupiter, the Planet, 53
„ Principal Facts about, 61, 62
„ Satellites of, 54, 62

Kepler, 33, 63, 94, 95, 105

Lacertids (Meteor System), 68, 69
Lalande's Star Catalogue, 114
Latitude, Astronomical, 14
Length of day at various latitudes (see Chart of the World, plate 20).
Leonids (Meteor System), 68, 69
Leverrier, 59
Librations of the Moon, 76
Lick Refractor, 97

PAGE
Light-year, the unit of stellar distance, 20
Light, received by planets from the Sun, 61
„ Time taken to reach the Earth from the Stars, 20, 21
„ Velocity of, 15
Limb of the Sun, darkening of, 37
Local and Standard Time, 117
Longitude, Celestial, definition of, 14
„ Terrestrial, 117
Lucifer, the Morning Star, 43
Lunar Eclipses, 86, 87
„ Ecliptic Limits, 87
Lunation, 72

Magnifying Power of Telescopes, 109
Magnitudes of Stars, 114, 115
Magnitude of smallest Star visible in a given Telescope, 30
Malvasia, Marquis of, 100
Mars, the Planet, 48
„ Principal Facts about, 61, 62
„ Satellites of, 62
Mass of the Earth, 45
„ of the Moon, 75
„ of the Planets, 62
„ of the Sun, 35
„ of various Stars, 22
Mean Solar Time, 117
Medusa (Minor Planet), 51
Mercury, the Planet, 41
„ Principal Facts about, 61, 62
„ Transits of, 42
Meridian Circle, The 102
„ Instrument of Eratosthenes, 91
Mersenne, 97
Meteors and Shooting Stars, 68, 70
„ and Meteor Streams, 68
„ and Comets, their connection, 70, 71
Meteor Showers, 70
„ Systems, Table of, 69
Meteorites, 70
„ Chemical Elements found in, 71
Metonic Cycle, 85
Micrometer, 100
Milky Way, or Galaxy, 30
Mimas, The innermost Satellite of Saturn, 62
Minor Planets or Asteroids, 51, 52
Mira, The Variable Star, 26
Month, its Origin, 2
„ Different Kinds of, 73
Moon, The, 72
„ Absence of Water in, 81
„ Apparent Angular Velocity of, 73
„ Craters on the, 77
„ „ Dimensions, &c., 79
„ Density of the, 75
„ Eclipses of the, 86
„ Ecliptic Limits of the, 87

PAGE
Moon, Elements and Principal Facts about, 62, 80
„ Librations of, 76
„ Mountains of, and their height, 77
„ Orbit of the, 74
„ Phases of the, 72
„ Rotation of the, 75
„ Sea-beds of the, 76
„ Size of the, 75
„ Surface, character of the, 76, 77
„ Telescopic appearance of the, 76
„ Walled Plains on, 78
Motion of Stars in the line of sight, 17, 18, 107
„ of the Sun in space, 23
Motions, Proper, of the Stars, 17, 18
Mountains, Lunar, their height, 17
Movement in Orbit of the Planets, 67
Mural Circle, The, 102
Muscids (Meteor System), 69

Names of the Constellations, 113
„ of the Satellites of the Planets, 62
„ of the Stars (*see Star Catalogue*, p. 127).
Nebula, The Spiral, 29
Nebulæ, 29
„ Annular, 29
„ Distribution of, 29, 30
„ Planetary, 29
„ Spectra of, 107
Negative Eye-piece for the Telescope, 110
„ Star-magnitudes, 115
Neptune, The Planet, 59
„ Principal Facts about, 61, 62
„ Satellite of, 59, 62
New Stars, 28
Newton, Sir Isaac, 13, 63, 96, 97, 105, 108
Newtonian Telescope, The, 97, 98
Nodes of the Lunar Orbit, 74
Nodical Month, The, 73
Nucleus of a Comet, 66
Nutation of the Earth's Axis, 15

Oberon, The Outer Satellite of Uranus, 62
Object Glass, The Chromatic, 95
„ The Achromatic, 96
Oblateness or Ellipticity of the Earth, 45
Obliquity of the Ecliptic, 47
Occultation of Stars, Circle of Perpetual, 11, 12
Olbers, 51
Orbit of the Earth, 46, 61
Orbits of Binary Stars, 24, 25
„ of Comets, 64, 66
„ of Planets, 61
Orionids (Meteor System), 69

P., Contraction for Piazzi's Star Catalogue, 114
Pallas (Minor Planet), 51

PAGE
Parallactic Rules, The, 92
Parallax of the Moon, 74
„ of the Stars, 20, 21
„ of the Sun, 33
Paths, Apparent, of the Stars, 11
Pegasids (Meteor System), 69
Pendulums for Astronomical Clocks, 103
Penumbra of the Earth's shadow in Eclipses, 87
„ „ Moon's shadow, 89
Penumbral lines, 89
Perigee and Apogee of the Lunar Orbit, 74
Perihelia of Comets, Distribution of, 71
Perihelion of the Earth's Orbit, 45
Perseids (Meteor System), 69
Phainomena of Eudoxos, 3
Phases of Mercury, 41
„ of Venus, 94
„ of the Moon, 72
Phobos, the inner Satellite of Mars, 50, 62
Phosphorus, The Morning Star, 43
Photosphere of the Sun, 37
Piazzi, 51, 114
Planetary Data, Table of, 61-62
Planetary Nebulæ, 29
Planetary System, 39
Planetoids (*see* Asteroids), 51, 52, 61, 62
Planets, Comparative Sizes of, 39
„ Elements, and Principal Facts about the, 61, 62
„ Intra-Mercurial, 40
„ Symbols of the, 61
„ Trans-Neptunian, 60
Plato (Lunar Crater), 78
Pleiades, Star Cluster, 28
Pole of the Earth, 11, 12, 13
„ „ its place affected by Precession, 13
Pole of the Ecliptic, 13
Pole Star, Ancient, Present, and Future, 13
Positive Eye-pieces for Telescopes, 110
Praesepe, Star Cluster, 28
Precession of the Equinoxes, 12
„ „ „ Cause of, 13
„ „ „ when discovered, 13
Prime Vertical Transit Instrument, 107
Prominences or Protuberances of the Sun, 37
Proper Motions of the Stars, 17
Ptolemy, 33, 92, 112, 114

Quadrantids (Meteor System), 69
Queen of Nebulæ (in Andromeda), 29

Radiant Point in Meteoric Showers, 68
„ Points of Meteor Systems, Table of, 69
Reflecting Telescope, various forms, 97
Refracting „ Simple, 95

PAGE
Refracting Telescope, Achromatic, 96
Repulsive Force acting on Comets, 68
Retarding Medium acting on Comets, 66
Retrograde Movement of Satellites of Uranus & Neptune, 58, 59
„ „ of some Comets, 64, 65
Reversal of the Spectrum, 106
Rhea, the fifth Satellite of Saturn, 62
"Rice Grains," 37
Right Ascension Defined, 14
„ „ determined by the Transit Instrument, 102
Rings of Saturn, 56, 57
Roemer, 54, 100, 107
Rosse, Lord, his Great Telescope, 99
Rotation of the Earth, 46
„ of the Moon, 75
„ of the Planets, 62
„ of the Sun, 36

Samarcand Observatory, 93
Saros, The, 85; Discovery of, 90
Satellites of the Planets, 62
Saturn, The Planet, 55
„ Cassini's Division in the Ring of, 56
„ Crape Ring of, 56
„ Dimensions of the Rings of, 57
„ Principal Facts about, 61, 62
„ Satellites of, 56, 62
Seas (Old) in the Moon, 77
Seneca, 63
Separating Power of Telescopes, 111
Sextant, 108
Shadow Cones in Eclipses, 86, 88
Shadow of the Earth in Lunar Eclipses, 87
„ of the Moon in Solar Eclipses, 89
„ „ „ „ Velocity of, on the Earth, 89
Shepherd's Star, The, 43
Shooting Stars, 68
„ „ Materials of, 71
„ „ Showers of, 70
Short, 98
Showers, Meteoric, 70
Sidereal Day, 46
„ Month, 73
„ Time, 103, 126
„ Year, 46
Siderites and Siderolites, 70
Signs of Zodiac, 14
„ „ „ No. of Degrees in a, 14
Sirius, Size, Spectrum, &c., 22
Solar Apparent Time, 117
„ Eclipses, 88
„ Ecliptic Limits, 88
„ Solstices, 91
Spectra of Comets, 67
„ Nebulæ, 29, 107

PAGE
Spectra of Stars, 21, 22, 107
„ Sun, 105, 106
Spectroscope, how used in astronomical research, 18, 24, 28, 29, 37, 107
„ how the Velocity of a Star is determined by it, 107
„ Principles of, 105
Sphere, the Celestial, 107
Spherical Aberration of a Lens, 96
„ „ Tests for, 109
Stars, Actual Velocity of, in Space, 18
„ Ancient and Modern Position of the brighter, 14
„ Binary, 24, 25
„ Catalogues of, 112, 114
„ Charts of, 115
„ Chemical Elements recognised in, 22
„ Classes of, 22, 23
„ Clusters of, 28
„ „ Distribution of, 29, 30
„ Designation of Individual, 114
„ Distance of, 19, 21
„ „ how determined, 20
„ Double, 24
„ Magnitudes, Methods of designating, 115
„ „ Negative, 115
„ Multiple, 24
„ Motions of the, Apparent and Actual, 11 to 18
„ Nature of the, 21
„ Numbers of, in each Magnitude, 29, 115
„ Positions, how affected by Precession, 12, 13, 14
„ Shooting, 68
„ Spectra of, 22, 23, 107
„ Temporary, 28
„ Time taken by their Light to reach the Earth, 21
„ Triple, 24
„ Variable, 25
„ Visible to the naked eye, 29
„ „ with different sizes of Telescopes, 30
„ „ and invisible at different latitudes and time of the year, 12
Stereographic Projection, 117
Sun, The, 33
„ Atmosphere, 37, 66
„ Chemical Elements in Atmosphere of, 106
„ Chromosphere, 37
„ Comparative Brilliancy of, 36
„ Corona, 38
„ Cyclones in, 37
„ Darkening of Limb, 37

PAGE
Sun, Density of the, 35, 38
„ Direction of Motion in Space, 23
„ Distance according to Ancients, 33
„ „ „ to modern determinations, 34
„ Eclipses of, Annular, 88
„ „ „ Total and Partial, 85, 86, 88
„ Equatorial Acceleration of Rotation, 36
„ Facts about, 38
„ Faculae, 37
„ Granules, 37
„ Heat and Light, how maintained, 36
„ Interior of the, 37
„ Light, 35, 36
„ Parallax of, how determined, 33
„ Photosphere of the, 37
„ Prominences or Protuberances, 37
„ "Rice Grains," 37
„ Rise and Sunset, Table for finding the Time of, 120
„ Rotation of the, 36
„ Size, 35
„ Spectrum Classification of, 23
„ Spots, 36
„ „ Location of, 36
„ „ Periodicity of, 23, 36
„ Temperature of, 36
„ *Umbra* of the Spots on the, 37
„ Velocity of, through Space, 22
Synodical Revolution of the Moon, 73
Syzygy, or Times of New and Full Moon, 72

Tables in the body of the volume (*see* list on page xi.)
Tails, or Trails of Comets, 67
Taurids (Meteor System), 69
Telescope, Achromatic, The, 96
„ Chromatic, The, 95
„ Defects in the, 109
„ Equatorial adjustment for small, 110
„ Equatorial mounting for, 104
„ Eye-pieces for the, 110
„ Finders for the, 110
„ Instructions for using a small, 109
„ Invention of Reflecting, 97
„ Invention of Refracting, 94
„ Largest Reflecting, 99
„ „ Refracting, 96
„ Magnifying power of, To find the, 109
„ Reflecting, Modern, or silver-on-glass, 99
„ „ Old, 97
„ Refracting, Modern, with double object glass, 96

PAGE
Telescope, Refracting, Old, with single object glass, 95
„ Stands for a small, 110
„ Tests for a small, 109
Temporary Stars, 26, 27, 28
Tethys, The third Satellite of Saturn, 62
Thales, 3
Time, Apparent, Civil, Sidereal, 46, 47, 117
Timocharis, 91
Titan, the sixth and largest Satellite of Saturn, 62
Titania, the third Satellite of Uranus, 62
Trains of Meteors, 68, 70
Transit Circle, The, 102
Transit Instrument, The, 100
Transits of the inner planets, 40, 42, 44
Trans-Neptunian Planet, 60
Triple and Multiple Stars, 24
Twilight, Duration of, in different latitudes, 121
Tycho (Lunar Crater), 78
Tycho Brahé, 63, 93, 100, 112

Ulugh Begh, 93
Umbra or Earth's shadow, 87
„ or Moon's shadow, 89
„ of Sun-spots, 37
Umbriel, the second Satellite of Uranus, 62
Unit of Stellar Distance, the Light Year, 20, 21
Uraniberg, 94
Uranus, The Planet, 58
„ Principal Facts about, 61, 62
„ Satellites of, 58, 62

Variable Stars, Classes of, and Table, 25, 26, 27
Venus, Phases of, 94
„ Principal Facts about, 61, 62
„ The Planet, 43, 44
„ Transits of, 44
Vesper, The Evening Star, 43
Vesta, The Minor Planet, 51
Via Lactea, or Milky Way, 30
Vulcan, The Supposed Planet, 40

Walled Plains (Lunar), 78, 79
Water Clocks, 93
Wollaston, 105, 106

Year of the Ancients, 2, 91
„ Different Kinds of, 46

Zenith, or Point overhead, 4, 11
„ Telescope, 108
Zodiac, how and when invented, 2, 4, 5
„ Signs of the, and their Symbols, 14
„ „ Number of Degrees in the, 14
Zodiacal Light, 38

PRINTED BY GALL AND INGLIS, EDINBURGH.

4.1 I 613 d

LIBRARY OF CONGRESS
0 003 631 205 1